Edited by:

KATA FURHOLT, MARGAUX L. C. DEPAERMENTIER, MICHAEL KEMPF, MARTIN FURHOLT

BEYOND HETEROGENEITIES

New perspectives on social and cultural diversity from the Neolithic to the Bronze Age in the Carpathian Basin

SCALES OF TRANSFORMATION IN PREHISTORIC AND ARCHAIC SOCIETIES | 21

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Preface by the series editors

With this book series, the Collaborative Research Centre Scales of Transformation: Human-Environmental Interaction in Prehistoric and Archaic Societies (CRC 1266) at Kiel University enables the bundled presentation of current research outcomes of the multiple aspects of socio-environmental transformations in ancient societies. As editors of this publication platform, we are pleased to be able to publish monographs with detailed basic data and comprehensive interpretations from different case studies and landscapes, as well as the extensive output from numerous scientific meetings and international workshops.

The book series is dedicated to the fundamental research questions of CRC 1266, dealing with transformations on different temporal, spatial and social scales, here defined as processes leading to a substantial and enduring reorganisation of socio-environmental interaction patterns. What are the substantial transformations that describe human development from 15 000 years ago to the beginning of the Common Era? How did interactions between the natural environment and human populations change over time? What role did humans play as cognitive actors trying to deal with changing social and environmental conditions? Which factors triggered the transformations that led to substantial societal and economic inequality?

The understanding of human practices within often intertwined social and environmental contexts is one of the most fundamental aspects of archaeological research. Moreover, in current debates, the dynamics and feedback involved in human – environment relationships have become a major issue, particularly when we look at the detectable and sometimes devastating consequences of human interference with nature. Archaeology, with its long-term perspective on human societies and landscapes, is in the unique position to trace and link comparable phenomena in the past, to study human involvement with the natural environment, to investigate the impact of humans on nature, and to outline the consequences of environmental change on human societies. Modern interdisciplinary research enables us to reach beyond simplistic, monocausal lines of explanation and overcome evolutionary perspectives. Looking at the period from 15 000 to 1 BCE, CRC 1266 takes a diachronic view in order to investigate transformations involved in the development of Late Pleistocene hunter-gatherers, horticulturalists, early agriculturalists, early metallurgists and early state societies, thus covering a wide array of societal formations and environmental conditions.

The volume *Beyond heterogeneities: New perspectives on social and cultural diversity from the Neolithic to the Bronze Age in the Carpathian Basin* brings this region into focus with the contribution of 12 papers spanning the 7th to 2nd millennia BCE. The Carpathian Basin holds an important central geographical position, being located between the south-eastern and central parts of Europe. The region's well-known and ample historical record aside, in prehistoric archaeological

discourse it is referred to both as a region of transition and as a centre – a region of prehistoric innovation, in which crucial social and cultural developments emerged and from where they spread. All the presented Neolithic and Bronze Age case studies display heterogeneous material culture and settlement structure, and show how the populations in question integrated new influences into their pre-existing material culture and technological toolboxes, without ending up as homogeneous entities.

What is beyond heterogeneities? This is the question that was asked by the editors, and they structured the papers in four sections to answer it, via particular case studies, which focus on 1) population and settlement dynamics; 2) social transformations and inequalities; 3) enclosures and communal areas; and 4) economy and subsistence strategies.

As series editors, we are grateful to Nicole Taylor for helping us to realise the technical editing of this volume, Esther Thelen for the creation of the cover and for all the graphics support, and Suzanne Needs-Howarth for the copy editing. We thank also the team at Sidestone Press for the smooth organisation of the publication process. Last but not least, we thank the volume editors for all their work.

Wiebke Kirleis and Johannes Müller

Beyond heterogeneities: New perspectives on social and cultural diversity from the Neolithic to the Bronze Age in the Carpathian Basin – an introduction

Kata Furholt, Margaux L.C. Depaermentier, Michael Kempf, Martin Furholt

Introduction

The Carpathian Basin is often referred to as a region with an especially important, central geographical position, being located between the eastern and western parts of Europe, as well as between south-eastern and central Europe. The ample historical record aside, in the prehistoric archaeological discourse, it is referred to both as a region of transition and as a centre – a region of prehistoric innovation, in which crucial social and cultural developments emerged and from where they spread. During the Upper Palaeolithic, some of the most elaborate pieces of portable art originate from the northern edges of the Carpathian Basin: the figurines of Willendorf, Galgenberg, Dolni Vestonice and Moravany (Dixson and Dixson 2012).

Most notable is the re-organisation of early farming lifeways into the Linearbandkeramik (LBK), or Linear Pottery culture during the mid-6th millennium BCE, a new package of socio-economic practices, cultural norms and object types emerged, which at 5350 BCE started to rapidly expand north, north-west, north-east and east and whose effects largely structured the trajectories of the following, Neolithic period, from the Paris Basin to the Dniestr River (Jakucs *et al.* 2016; Whittle *et al.* 2016; Staniuk *et al.* 2020; Weninger 2020).

Early Copper metallurgy connected the Carpathian Basin with south-eastern Europe in the 5th millennium BCE, and some of the most important Copper Age cemeteries are found in the Carpathian Basin (Bognár-Kutzián 1963). Early wagon technology is prominently depicted in Baden-period graves of the 4th millennium BCE, emphasising the Danube as a route for spreading crucial technological innovations (Maran 2004a, b; Bondár 2006, 2008, 2012; Müller 2013).

The expansion of Yamnaya-style kurgan burials connects the Carpathian Basin to the Pontic Steppe, again indicating the continental importance of the region in 3rd millennium migration processes (Gerling, Bánffy, *et al.* 2012; Gerling, Heyd, *et al.* 2012; Kulcsár 2013; Dani 2020; Jarosz *et al.* 2021, 2021; Włodarczak 2021). During the Bronze Age, the Carpathian Basin is archaeologically defined by a plethora of culture groups (Bóna 1992), some of which display what is considered to be among the most elaborate material culture known in European prehistory, while Carpathian bronze objects also appear in regions as distant as southern Scandinavia (Anthony 2007; Vandkilde 2014). The largest and most visibly central settlements of the period appear in the Carpathian Basin (*e.g.* Vráble 'Fidvár', Nižná Myšľa, Cornești-Iarcuri) (Gogâltan 2008; Heeb *et al.* 2008; Bátora *et al.* 2009, 2012; Szentmiklosi *et al.* 2011; Jaeger and Olexa 2014; Jaeger *et al.* 2021, 2023). It quickly becomes obvious that the Carpathian Basin plays a major role in understanding prehistoric socio-cultural trajectories and transformation processes across Europe, merging multiple lifeways and perceptions as well as integrating population dynamics, mobility and communication corridors among Early Neolithic and Bronze Age groups.

This book builds upon the oral and poster presentations of the session 'The Carpathian Basin as a melting pot? Perspectives on social and cultural diversity from the Neolithic to the Bronze Age', held at the annual meeting of the European Association of Archaeologists (EAA), in Kiel, in 2021. It was originally planned for the 2020 EAA meeting in Budapest, but as this was largely postponed to 2022 due to the COVID-19 pandemic, we were able to motivate many of the original contributors to participate in the digital 2021 annual meeting organised in Kiel.

During the fruitful discussion portion of the session, we decided to remove the melting pot metaphor from the session title. A melting pot is a powerful visual symbol of the mixture of diversities, but it implies that everything then ends up as a homogenised whole. However, as is obvious from the contributions in this volume, all the presented Neolithic and Bronze Age case studies display a heterogeneous material culture and settlement structure and portray how the populations in question integrated new influences into their pre-existing basic material culture and technological toolboxes, without ending up homogeneous. In contrast, hybrid combinations of Starčevo – Körös and Vinča – Tisza pottery styles in the southern part of the Carpathian Basin and the northern part of the Balkans are fabulous examples of transfer of technological knowledge and exchange of material culture, which result in diverse transformations in the social and cognitive lives of those people. Also, new impulses emerge from them. We, therefore, changed the wording of the first part of the title to 'beyond heterogeneities', as better capturing the main theme addressed. This term refers to the dual, and seemingly contradictory, characterisation of the Carpathian Basin in prehistory as being both centre and transitional zone. We would like it to be understood as a reference to the fact that the Carpathian Basin is two things at once. It is a region in which different transregional influences and trends meet, creating a new, heterogeneous cultural landscape. At the same time, the Carpathian Basin is the space where those diverse ideas, norms and practices merge and are recombined in a creative manner. It is a region central to giving rise to new socio-economic and cultural expressions, which subsequently had a profound influence on societies all over Europe during prehistory.

Furthermore, the geographical term Carpathian Basin is also not unproblematic, as it is often used to refer to different areas. There are alternatives, such as the Pannonian Plain, the Great Hungarian Plain, the Great Hungarian Basin, or the Alföld, which refer to largely the same area but have obvious political implications. We stick to the term Carpathian Basin, as it is the term that is internationally best known, even if we do not cover all its parts.

The Carpathian Basin as geographical and cultural unit

The Carpathian Basin, situated at the western edge of the Eurasian Steppe Belt, in east-central Europe, has undergone significant environmental and socio-cultural changes throughout the Holocene (Fig. 1). More recently, it has experienced extensive alterations to its landscape due to contemporary land-use changes and economic development. Agricultural production has played a pivotal role in the region's modernisation process, driven by the different states in that region — Hungary, Yugoslavia, Serbia, Romania and Slovakia — during the 19th and 20th centuries, leading to ecological imbalances caused by extensive surface drainage, canalisation activities, and subsequent wind erosion and soil loss. Consequently, the modern landscape of the Carpathian Basin bears various human-made impacts that complicate the interpretation of prehistoric landscapes using contemporary geographical data.

Climatic conditions

Nowadays, the Carpathian Basin experiences predominantly moderate continental climates, with some maritime influences (Ács *et al.* 2015; Demény *et al.* 2013). The geographical layout of the Carpathian Basin accentuates these continental characteristics, resulting in dry conditions and an annual average rainfall of less than 500 mm in its central parts (Kiss *et al.* 2015; Jakab *et al.* 2009). These challenging climatic conditions further intensified during the Holocene due to arid winds, reducing vegetation cover to steppe or forest-steppe landscapes and contributing to the accumulation of dust deposits (Gardner 2002; Novothny *et al.* 2010; Magyari *et al.* 2010; Uj *et al.* 2016; Willis *et al.* 1997; Willis *et al.* 2000). Subsequently, in the Boreal phase, warmer and drier conditions prevailed, leading to the widespread presence of grassland vegetation (Hertelendi *et al.* 1992; Magyari *et al.* 2010; Magyari 2011). During the Atlantic phase, a period known as the climatic optimum coincided with the emergence of early farming activities and the Early Neolithic in the Carpathian Basin (Hertelendi *et al.* 1992; Magyari *et al.* 2001; Hedges *et al.* 2013).

Geological and sedimentary conditions

Large portions of the Great Hungarian Plain are covered by Quaternary sediments comprising gravel, sand, silt and clay (Kercsmár *et al.* 2015). The Upper Pleistocene loess, a distinctive feature, is primarily found along the hilly peripheries of the plain; the Mezőföld region, west of the Danube; and the alluvial fans within the basins. However, the origin, thickness and age of these sedimentary units can vary locally, with sections exhibiting discontinuous sequences (Varga 2011). These deposits can frequently alternate with layers of sand and palaeosols formed during warmer and wetter interglacial periods (Kovács *et al.* 2013). Notably, extensive sand deposits are prevalent in the Danube – Tisza interfluve (DTI) and the Kiskunság region, east of the Danube (Kercsmár *et al.* 2015).

Moving to the geological features of the Carpathian Basin, we note that the Transdanubian Range (Dunántúli-Középhegység) extends from the Keszthely Mountains to the Pilis-Visegrád Mountains. It primarily comprises Triassic formations, with sporadic outcrops of Palaeozoic patches in the Velence Mountains and extensive Mesozoic formations in the Bakony and Gerecse Mountains. The North-Hungarian Mountains (Északi-Középhegység) are characterised by Miocene volcanic activity, resulting in andesite, dacite and (pyroclastic) tuff formations in the western part (Börzsöny Mountains) and Pliocene basaltic overlays in the

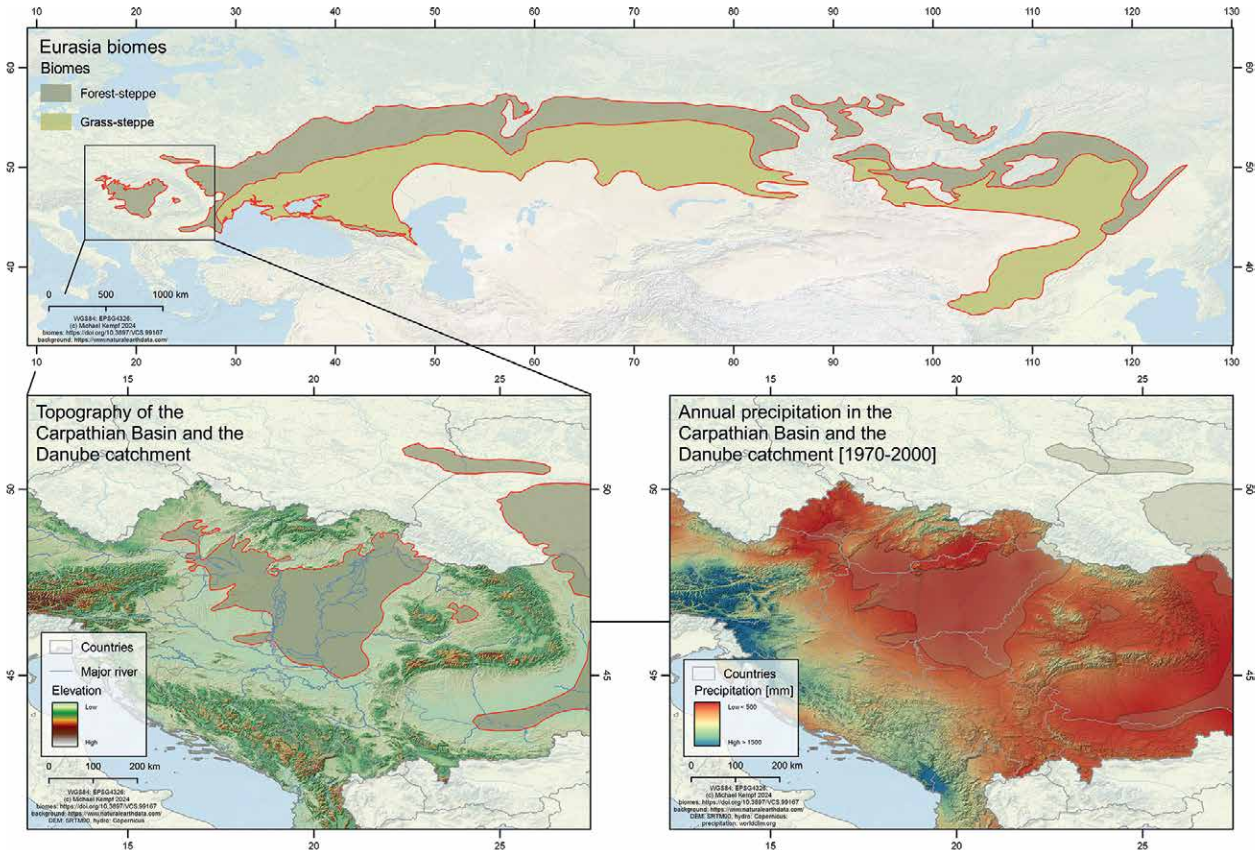

Figure 1. Map of the study region. The eastern part of the Carpathian Basin is the western-most part of the steppe region across Europe and Asia.

northern part. The eastern part (Bükk Mountains) primarily consists of thick Middle – Upper Triassic shallow marine carbonates and deep marine sediments, which underwent significant metamorphic folding, uplift and denudation during the Cretaceous and subsequent periods. South-western Slovakia exhibits a diverse array of geological units, prominently featuring the Carpathian orogenic belt and the Danube Basin. In this region, The Carpathian Mountains consist of various lithological formations, including flysch, sandstones and shales, reflecting their complex tectonic history of thrusting and folding. Adjacent to the Carpathians lies the Danube Basin, characterised by sedimentary sequences comprising predominantly Miocene and Pliocene formations, such as marls, sandstones and conglomerates, which provide insights into the region's depositional environments and palaeogeographic evolution.

In contrast, Pleistocene – Holocene aeolian sandy sediments are predominantly found in the Kiskunság and DTI regions (Obreht *et al.* 2019) and the Nyírség region (Ladányi *et al.* 2015). The floodplains are characterised by Holocene fluvial deposits (Kercsmár *et al.* 2015). The eastern part of the Carpathian Basin experiences significant floodplain dynamics and channel re-organisation driven by Late Pleistocene or Holocene rivers, such as the Tisza (Timár *et al.* 2005; Moskal-del Hoyo *et al.* 2018), the Körös (Petrovszki and Timár 2010), and the Maros (Kiss *et al.* 2014). Neotectonic movements have compelled the drainage system to fill depressions in subsiding plains. From the end of the Pliocene, the crustal uplift of the mountains diverted the Danube's flow eastward, leading to the deposition of hundreds of metres of fluvial sediments in the Great Plain (Gábris 1994; Horváth *et al.* 2006).

Local soil development and quality are significantly influenced by fluvial deposits. However, surface modifications and transformations, such as intense land use, wind-driven erosion, and groundwater lowering, have had a substantial impact on soil textures at the local to micro-regional scale. This has resulted in a

very fine-grained soil mosaic that does not always align with broad geological classifications (Várallay 1989; Birkás *et al.* 2004; Laborczi *et al.* 2016). László Pásztor and colleagues have established a spatial soil information system for Hungary that has enhanced the resolution and quality of the Hungarian soil classification system. This classification system allows for the differentiation of soil textures and types, as well as the assessment of degradation, salinisation and erosion levels (Schofield *et al.* 2001; Pásztor *et al.* 2012, 2016). Additionally, it provides insights into wetland development, floodplain characteristics, and vulnerability to flooding (Pásztor *et al.* 2015; Bozán *et al.* 2018).

Lithomorphic soils are notably abundant in the northern mountain ranges and on eroded slopes composed mainly of limestone, dolomite, basalt and andesite. In the loess-covered plains, Chernozems predominate and often exhibit significant salt-related soil properties due to the presence of saline groundwater in the central part of the plain (Dobos *et al.* 2000; Magyari 2011; Schofield *et al.* 2001; Tóth *et al.* 2001). In the DTI region, sandy soils with localised salt derivatives are the dominant pedological units (Tóth *et al.* 2001; Dobos *et al.* 2000; Mádl-Szőnyi *et al.* 2008).

Hydrological conditions

The hydrological system in the Carpathian Basin is significantly shaped by the sedimentation processes that occurred during the Late Pleistocene and early Holocene. The extensive alluvial plain along the River Danube is delimited to the east by an elevated plateau-like palaeo-alluvial fan. This fan was later incised during flooding events and avulsion processes, leading to the shifting of alluvial deposits (Ujházy *et al.* 2003; Knipl and Sümegi 2012). The Tisza, a major tributary of the Danube, plays a crucial role in this hydrological system (Kasse *et al.* 2010). The subsidence processes affecting the Alföld have had a significant impact on drainage and hydrological developments (Fig. 2). Consequently, the broad floodplain of the River Tisza is characterised by extensive alluvial fans with remnants of palaeo-channels. These fluvial deposits primarily consist of fine-grained materials, such as clay, silt and sand (Timár *et al.* 2005; Kasse *et al.* 2010; Nádor *et al.* 2011; Kiss *et al.* 2015; Moskal-del Hoyo *et al.* 2018). These sediments have been distributed and frequently remobilised across the entire floodplain due to channel shifting and avulsion events (Kasse *et al.* 2010; Kiss *et al.* 2015)

Landscape history and heterogeneity

Modern surfaces pose a challenge when we compare them with premodern environmental conditions, due to various factors that have altered the landscape. Wind erosion and the accumulation of sandy and silty materials (Négyesi *et al.* 2019; Obreht *et al.* 2019), along with the erosive and accumulative dynamics of riverbeds and floodplains in the Carpathian Basin's diverse hydrological systems (Chu 2018), have led to changes in landscape composition and the potential habitats for anthropogenic, faunal and floral life during the Pleistocene and the Holocene. This has resulted in a fragmented geological and pedological landscape with micro-site vegetation refuges, influenced by local tectonic activity and subsidence processes (Magyari 2011).

The course of the River Danube was redirected to the west, creating abandoned palaeo-channels that have shaped the DTI. This change led to the accumulation of sandy alluvial deposits, contributing to the characteristic sandy loess surface coverage of the DTI. Similarly, the Tisza has undergone tectonic and geomorphological alterations in its riverbed. Before transitioning into a meandering streamflow character, the character of the palaeo-Tisza displayed anastomosing features, making it susceptible to subsequent channel avulsion events. These events

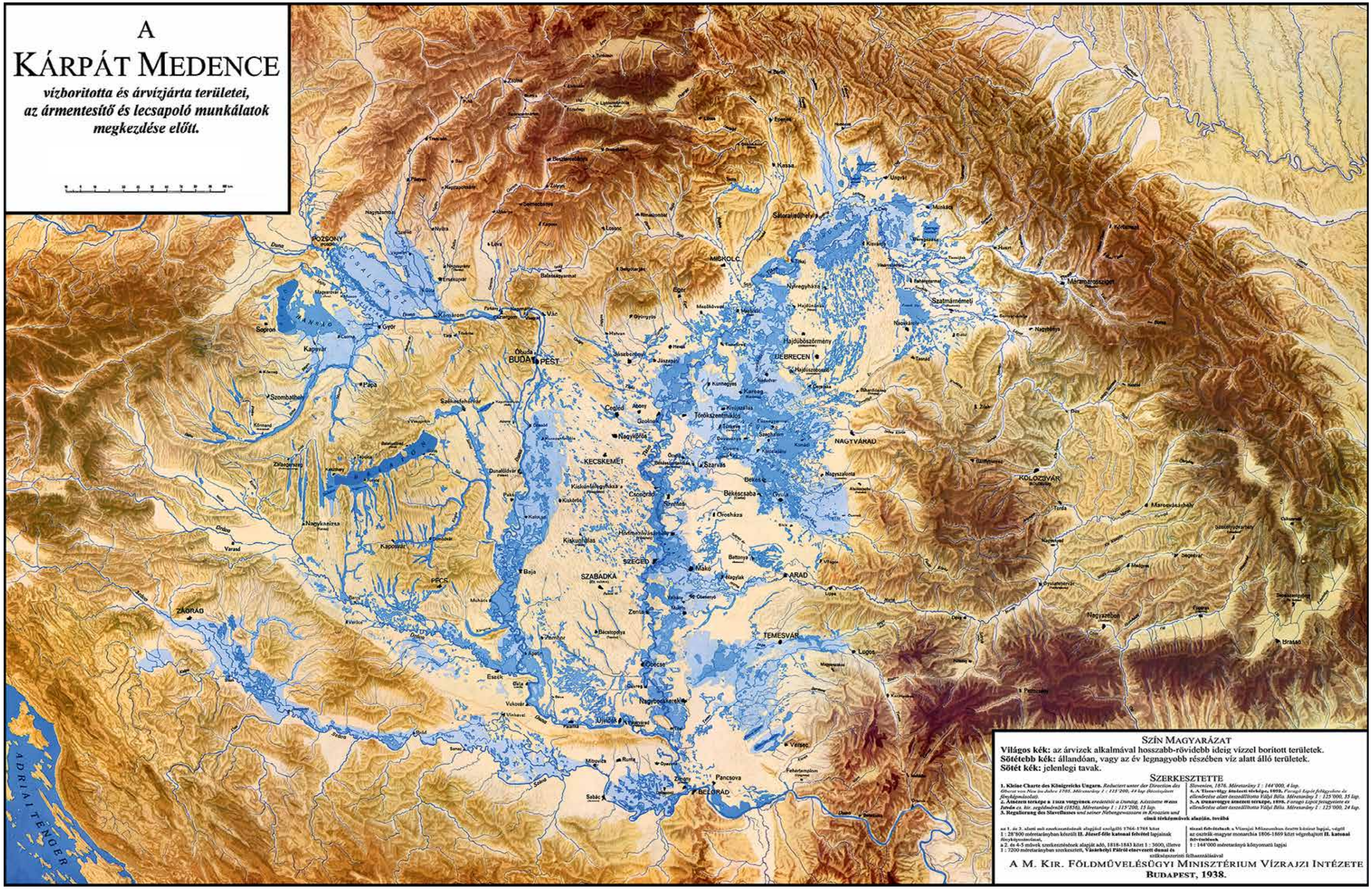

Figure 2. The well-known 'puddle map' (Hungarian: pocsolyatérkép), which was published by the Hydrographic Institute of the Royal Hungarian Ministry of Agriculture in 1938. The map shows the hydrography of the Carpathian Basin before the intensive river regulations of the late 19th and early 20th centuries (Source: https://map.mbfsz.gov.hu/terkepekamultbol/Mo_arviz_1938/).

resulted in a broad floodplain and a riverbed that ran approximately 80 km east of its current trajectory (Timár *et al.* 2005; Nádor *et al.* 2007; Chu 2018). These changes left behind sandy islands rising from the floodplain, which are remnants of the levees of the early Holocene river system (Sherratt 1983).

In conjunction with Late Pleistocene loess accumulation, the wind-driven redistribution of fine-grained and sandy materials during cold and dry climatic periods has created a localised soil mosaic. This mosaic includes fertile chernozem, forest brown soils, and extensive meadow soil corridors along the active river channels. All of these soil units are interspersed with sandy outcrops, salt-affected areas, and alluvial and peaty soil conditions in humid depressions or along small-scale, low-velocity river systems.

Although the Alföld may appear to have uniform geological conditions due to the prevalence of extensive fluvial deposits consisting mostly of sandy material, the soil texture and the soil units reveal a tendency towards small-scale and local soil mosaics across the Carpathian Basin and adjacent regions.

The geological signal provides insights into macro-regional and micro-regional surface characteristics. However, geological units alone may not be sufficient to convey information about immediate soil texture and units at the local level. When considering Neolithic land-use strategies and site-catchment activities of individuals and groups, it becomes essential to understand very local soil conditions; freshwater access; and vulnerability to extreme events, such as flooding as primary location factors.

Environmental variability is determined not solely by distinct geological units, but also by observed floodplain dynamics, the extent of potential flooding events, erosion and accumulation processes, and the resulting local soil and vegetation patterns on fragmented surfaces. Particularly, floodplain dynamics and the formation of early Holocene river channels and islands within broad alluvial sandy fans have shaped a constantly changing landscape. These changes can still be identified through, for example, palaeo-channel mapping based on analyses of satellite images.

Modern land-use strategies and vegetation coverage, whether cropland, forested areas or barren terrain, offer insights into high- and low-quality soil conditions, waterlogging and vulnerability to flooding. Despite extensive anthropogenic modifications in the past two centuries, the locations of palaeo-channels can still be discerned through ploughing patterns.

The structure of this volume

Our perspectives on social and cultural diversity are grouped into four main topics. In the first part, five contributions deal with the dynamics of population and settlement, ranging from Early Neolithic palaeo-demography, to settlement pattern analyses, to the discussion of new excavation and prospection data. Part 2 deals with social transformations and the development of inequality, in three contributions, focusing on the settlement site of Gradište, Serbia; the Bronze Age cemetery of Jelšovce, Slovakia; and the Bronze Age settlement and cemetery site of Kajászó, Hungary. Part 3 assembles two papers dealing with the interpretation of the enclosure sites at Vráble, Slovakia, and Borđoš, Serbia. Finally, in Part 4, two papers focus on the economy and subsistence practices, using cases from the Slovakian Lengyel culture and the site of Karancsság, in north-eastern Hungary.

Brief summary of the articles

Population and settlement dynamics

One of the keys to understanding the spread and development of Neolithic societies in central Europe is to consider both internal and external factors that might have influenced this spread coming from the south. In this context, three contributions provide various methodological and conceptual approaches to investigate the Neolithic population and settlement dynamics in the region.

In their paper entitled **'Starčevo – Körös – Criş regional and macro-regional palaeo-demography'**, Tamara Blagojević, Marko Porčić and Sofija Stefanović present a study of the population dynamics during the first stages of the Neolithic in central Europe. They apply the summed calibrated radiocarbon probability distributions method at the regional and macro-regional levels to estimate the role of demographic processes in the spread of the Starčevo – Körös – Criş cultural complex in this region. This approach enables them to disentangle general trends from locally specific developments related to environmental or socio-economic factors. The authors, moreover, consider bias in datasets and methods and integrate tests for statistical significance. The most striking result is the particularly intensive and significant population growth observed at the beginning of the period in all regions, supporting the Neolithic demographic transition theory. This is considered a potential further line of evidence for the travelling wave-front model, with migratory inputs from the Balkan regions, as introduced by Silva and Vander Linden (2017). In the subsequent chronological phases, several regions show a short-term stabilisation followed by a decline in population size, which, overall, confirms the 'boom-and-bust' fluctuations attested from previous studies – although a later peak in the population curve may correspond to a consolidated socio-economic structure, enabling a peak in fertility. Even though regional disparities are highlighted in the paper, the authors stress the limits of the method with respect to small sample sizes. The study nevertheless provides important baseline data for future research.

In another attempt to understand the processes underlying the spread of the Neolithic way of life, the paper **'Exploring Neolithic site preferences on the River Tisza floodplain using point-pattern analysis and multicomponent environmental models'**, by Michael Kempf, Gerrit Günther and Margaux Depaermentier, offers a computational approach to integrating environmental and socio-economic variables in the investigation and understanding of site distribution in the Tisza region across the Neolithic. This analysis uses multivariate statistics and point-pattern analysis of site databases in a diachronic perspective from the Early to the Late Neolithic to assess site preferences in terms of landscape affordances and to trace transitions in spatial site location parameters over time. In this context, the authors present and discuss continuity and change in site preferences with respect to environmental covariates, including topography, hydrology and pedology. This study also considers potential bias and gaps in the databases, related to research history and modern infrastructure. Although there is some evidence for 'artificial' densities – especially regarding Early Neolithic sites – the observed shifts in site location are already significant between the Early and the Middle Neolithic, and they become even more considerable in the Late Neolithic. Hence, Middle and, in particular, Late Neolithic settlements overall do not seem to be a function of the settlements from the previous periods. Other factors are (also) triggering this evolution. These patterns can hence be put into perspective with changes in climate, social, technical and economic conditions, as well as in subsistence strategies. Overall, this paper provides an innovative, step-by-step methodology to estimate spatial patterns and site development on broad chronological scales.

Another contribution, **'The possible effect of plant cover on wind comfort in the Late Neolithic: A case study using environmental reconstruction for the site of Makaranda (northern Serbia)'**, by Aleksandar Medović, Robert Hofmann, Martin Furholt, Tijana Stanković Pešterac, Ildiko Medović, Stefan Dreibrodt, Liudmyla Shatilo, Kata Furholt, Fynn Wilkes, Darko Radmanović and Nikola Mrkšić, is dedicated to the consideration of environmental factors in the development of settlement dynamics. Using a comprehensive and interdisciplinary approach integrating archaeological, geomagnetic, macro-botanical, botanical, anthracological, palynological, geomorphological, malacological, palaeoclimatological and climatic proxies from the Late Neolithic sites of Prečka, Borđoš and Makaranda, the authors present a reconstruction of the local natural environment at Makaranda. By comparing these results with patterns in settlement parameters, and especially by considering the main wind direction and intensity during summer and winter, the authors present a new interpretation of the orientation of Neolithic houses and their integration in the landscape, which, in turn enables a reconstruction of environmental settings at the micro level. Hence, in order for the inhabitants to meet the need to protect themselves from cold and intense wind over the course of the year, a combination of various trees and shrubs was needed in the surroundings. The selection of building materials having specific thermophysical properties and the management of house wall thickness enhanced the comfort of Late Neolithic populations at Makaranda. However, not only environmental, but also cultural and ritual factors are considered to have been decisive in the choice and organisation of a settlement area.

The next paper in this part of the volume, **'Neolithic settlement structures on the lower reaches of the River Tisza (Vojvodina, Serbia): The results of archaeomagnetic prospection'**, by Robert Hofmann, Kata Furholt, Aleksandar Medović, Martin Furholt, Fynn Wilkes, Ildiko Medović, Tijana Stanković Pešterac, Till Kühl, Sebastian Schultrich, Raško Ramadanski and Lenkskaya Martinova, presents new magnetic plans and results of several, mostly Late Neolithic, settlements along the lower reaches of the River Tisza. In this paper, the Serbian – German team summarises the last few years of fieldwork and publishes those plans for the first time, together with some primary interpretations of newly measured settlements. They looked more closely at how these new settlements are related to the multicomponent site of Borđoš and discuss the significance of the different settlement layouts found, not least in relation to the aggregation processes during the Late Neolithic in this region, and a potential settlement hierarchy in the Lower Tisza region. Together with the other Neolithic case studies in this volume, this paper presents a valuable contribution to settlement research in the Carpathian Basin and the Lower Danube region, which has constantly improved thanks for the more widespread use of magnetic prospection as an indispensable survey method in archaeological field investigation.

Pál Raczky, András Füzesi, Gábor Mesterházy, Kata Furholt, Eszter Bánffy, Knut Rassmann, Máté Stibrányi and Gábor Serlegi give a new interpretation of one of the most well-known Late Neolithic stratified settlements of the early 5th millennium BCE, Szegvár-Tűzköves, which is located in the Great Hungarian Plain. In their contribution, entitled **'Szegvár-Tűzköves (Tisza region, Hungary): Teaching an old site new tricks'**, the authors present the results of a new geomagnetic survey and a re-evaluation of the archaeological records of the long-term excavation programme in the second half of the 20th century. They emphasise the value in considering the 'old excavation and its material' by applying new methods and rethinking the previous narrative to bring in a new perspective, not only at the local level, of the site, but also in a broader dimension. The new geomagnetic survey revealed an enclosure system of multiple ditches around the settlement, which extended circa 32 ha, including the almost 2 ha tell-like main habitation area. It is particularly the evidence of a tell-like monument in the central area that distinguishes this site from Cucuteni – Tripolye settlements with empty central areas, and with this monument, the site

shows similarities with the site of Hódmezővásárhely-Kökénydomb (also along the Lower Tisza). The settlement mound and the houses oriented towards a focal area formed a distinctive monumental spatial system on the southern portion of the Great Hungarian Plain in the early 5th millennium BCE. Besides the settlement structure, the paper focuses on the fragmented clay figurines and their meaning in the larger, regional context.

Social transformations and inequalities

Beyond providing a better understanding of human – environment interactions and of the role of pragmatism in the development of Neolithic societies, recent archaeological research also provides new insights into social structures and their crucial role in shaping the archaeological record.

The paper **'Social transformations of liminal areas in the Late Neolithic: A multidisciplinary approach to the site of Gradište (Serbia)'**, by Miroslav Marić, Silvia Amicone, Jelena Bulatović, Nemanja Marković and Neda Mirković Marić investigates the influence of major cultural and technical complexes on the development of domestic practices and social transformations in liminal areas during the Late Neolithic. The Late Neolithic site of Gradište, on the southern edge of the Pannonian Plain, was chosen as a case study for this purpose. In their study, the authors integrate archaeological and Bayesian chronological dating approaches to investigate the settlement development over time. They apply typological and statistical analyses of the ceramic materials, ceramic petrography, and X-ray diffraction to assess the level of technological know-how and the role of various traditions in the production of ceramic vessels. And they conducted a zooarchaeological analysis to study land-use and subsistence strategies. This interdisciplinary approach successfully highlights the prosperity of liminal areas during the Late Neolithic and their integration in regional socio-economic networks, which supported the development of complex societies.

The paper **'Circuits of reproduction: The opportunities and power to change'**, by Tamás Polányi, offers a theoretical approach to understanding the role of individuals' agency and political discourse in social and historical transformations. An empirical study of contemporary political discourse about gun violence in the USA first allows us to take into account circuits of reproduction. This implies that we need to consider the interplay between political discourse (including the materiality of communication) and the population's perception, consciousness, knowledge, decision making and agency. This emphasises that social and historical changes are long-term processes at the interplay between persistence and transformation. By integrating Giddens' theory of structuration and the concept of liminality in a ritual economy approach, Polányi interprets the human – material relations in the mortuary domain as a combination of habitual and political. In his study of the Bronze Age settlement and cemetery at Kajászó (Váli Valley, central Hungary), the author highlights both continuity and gradual changes in economic and social structures in the Váli Valley over centuries. He then shows evidence for improvisation and path dependence and hence for human agency and identity in mortuary practices. These, in turn, are considered likely manifestations of political discourse. This approach offers new perspectives for our understanding of social and historical transformations in both past and modern societies.

In their paper **'Applying the Inequality Possibility Frontier and the Inequality Extraction Ratio to archaeological data: Studying inequality in the Early Bronze Age cemetery of Jelšovce (Slovakia)'**, Fynn Wilkes and Henry Skorna apply quantitative methods to investigate social inequality in prehistoric societies. Using the Inequality Possibility Frontier and the Inequality Extraction Ratio (developed by B. Milanović) enables them to integrate the economic limitations of pre-industrial societies and hence to consider the maximal possible inequality in the calculation of the Gini index. In their case study of the Early Bronze Age cemetery of Jelšovce (Nitriansky kraj,

Slovakia), which is closely related to the contemporaneous settlement and cemetery at Vráble, they use anthropological data and information about the graves to determine a grave index value related to a subsistence and social (or wealth) minimum for each chronological (and cultural) phase. With this method, it is possible to record the movement of wealth and resources within the society. This reveals the role of surplus exploitation – as highlighted especially during the Únětice culture – and the economic situation in the appearance of social inequality.

Enclosure and communal areas

When considering these new perspectives related to social structures, inequalities, and transformations, it is possible to shed new light on intensively investigated archaeological features, such as the enclosures, and their societal meaning.

With their paper entitled **'Understanding the variability of deposition practices involving human remains in Neolithic settlements of the northern Carpathian Basin: The Neolithic site of Vráble (Nitra district, Slovakia)'**, Martin Furholt, Ivan Cheben, Alena Bistáková, Zuzana Hukeľová, Maria Wunderlich, Till Kühl, Nils Müller-Scheeßel and Kata Furholt go beyond the role of social inequality in the formation and transformation of prehistoric societies and discuss the role of magical practices and concepts in the funeral context. With this contribution, we stay in south-western Slovakia and focus on the LBK burials at the Neolithic site of Vráble (5250-4950 BCE). The authors lead a complex analysis of the unusual treatment of human bodies, such as the deposition of headless individuals close to the entrances of the enclosure, and suggest a revision of their traditional interpretation that these individuals had died as a result of warfare. By observing recurrent patterns in the spatial distribution of funerary depositions, they highlight a complex and multilayered set of ritual practices that involve both the community and some specific sections of the population at various levels. A comparison among similar contexts at the regional level further shows the recurrence of meaningful and patterned practices related to differential body deposition in enclosure ditches or pits, usually closely related to settlements. With this new conceptual approach, the authors consider the role of magic in the negotiation of individuality, community and settlement space. In their model, funeral practices are integrated into magical processes that could be perceived as a response to crises and complex social situations.

In their paper entitled **'Exploring the Late Neolithic ditch: New data on dating, subsistence and environment from a circular enclosure at Borđoš (Vojvodina, Serbia)'**, Robert Hofmann, Aleksandar Medović, Slobodan B. Marković, György Sipos, Sarah Pleuger-Dreibrodt, Randall J. Schaetzl, Milivoj B. Gavrilov, Milica G. Radaković, Ildiko Medović, Desanka Kostić, Stefan Dreibrodt, Fynn Wilkes, Tijana Stanković Pešterac and Martin Furholt place the focus on another enclosure, at Borđoš, building a bridge to the understanding of such contexts in the Late Neolithic. The authors led a multidisciplinary study and combined sedimentological, geomorphological, pedological, archaeological, archaeobotanical and zooarchaeological analyses, as well as numerical luminescence and radiocarbon dating, to clarify chronological and functional aspects of the backfilling processes of the ditch system at Borđoš. Here as well, the enclosure is understood as a communal infrastructure with special ritual (integrative) or economic or political functions, used to enhance cohesion within the village community. Moreover, the authors demonstrate that this enclosure is one of the earliest documented rondels spatially separated from an associated settlement in the entire Pannonian Plain – dating before 5000 BCE. The analysis of environmental data furthermore enables the reconstruction of the environment – in this case a pristine forest-steppe environment, including grassland with patches of xerothermic shrubs and small trees, which was overall adequate for settlement and agricultural activities. The mixed resources used in

the subsistence strategies suggest that this place was strategically chosen due to the diversity of the landscape offerings.

Economy and subsistence strategies

Finally, two contributions place the focus on local and regional economies, showing the capacity of the Neolithic population to adapt to, benefit from and exploit their immediate and surrounding environments.

In their paper **'The animal economy of the Lengyel culture population in Slovakia and the case study of Kiarov (central Slovakia)'**, Noémi Beljak Pažinová, Katarína Šimunková and Alena Bistáková present an archaeozoological case study from three Lengyel culture and Epi-Lengyel sites in Kiarov: Šimonovské ortovisko, Veľké ortovisko and Nad Kiarovskou. By analysing the faunal assemblages from various Lengyel cultural groups within the same region, they explore variations in animal exploitation practices as well as in spatial differences regarding the reliance on wild and domestic species. They furthermore critically discuss the limits of the study, caused by disparities in source availability and further bias. The archaeozoological study includes basic anatomical and taxonomic analyses, analysis of pathological or intentional bone lesions, and basic quantification. The authors demonstrate that during the entire period of occupation, the animal economy focused on domesticated livestock (including cattle, sheep, goats, and pigs, mainly kept for meat production), while hunting wild species only played a minor – maybe opportunistic – role in the subsistence strategies. The bones and antlers from wild species were probably collected and selected for tool manufacture and do not necessarily represent consumption debris; red deer and roe deer dominate the wild taxa attested at the sites. Spatial differences in the distribution and frequency of the recorded taxa can be related to site-specific traditions, preferences or even ecology and natural availability.

Kata Furholt presents an evaluation of a Middle and Late Neolithic lithic assemblage from the site of Karancsság (Nógrád region, in the foreland of the North-Carpathian Mountains) in her paper entitled **'Continuity in lithic tool production and raw material use at the Neolithic site of Karancsság, in the North-Hungarian Mountains (Nógrád county, Hungary)'**. By investigating raw material usage and technological processes, assessing the typological characteristics of the assemblage, and comparing the results with LBK and Lengyel datasets from the wider region, she provides a new interpretation of the lithic assemblage in terms of cultural transformations. After defining the lithics of each period, she emphasises the considerable similarities in both raw material and technological parameters between the LBK and Lengyel periods. She also points out that supra-regional material was given more attention and was in some cases reused several times, while local raw material was treated with less care. The reconstruction of tool production and the *chaîne opératoire* furthermore highlights the careful selection of material depending on production and object types, suggesting a high degree of technological know-how, which was rooted in the LBK and Lengyel traditions. The selection of raw materials and the production and use of the lithic tools reflect the well-established regional organisation of Middle and Late Neolithic economies in the north of the Subcarpathian regions.

In her concluding paper –**'Social and cultural diversity in the later prehistory of the Carpathian Basin: some implications'**– Eszter Bánffy emphasises the significance of the unique location of the Carpathian Basin, which comes to the fore in multiple prehistoric (and historic) epochs. She discusses the main research questions of the papers, points out the common scientific trajectories in other parts of Europe, and highlights the pivotal importance of understanding the new challenges accompanying the 'third science revolution'.

References

Ács, F., Breuer, H., Skarbit, N., 2015. Climate of Hungary in the twentieth century according to Feddema. *Theoretical and Applied Climatology*, 119(1-2), 161-169.

Anthony, D.W., 2007. *The horse, the wheel, and language: how Bronze-Age riders from the Eurasian steppes shaped the modern world*. Princeton, NJ: Princeton University Press.

Bátora, J., Behrens, A., Gresky, J., Ivanova, M., Rassmann, K., Tóth, P., Winkelmann, K., 2012. The rise and decline of the Early Bronze Age settlement Fidvár near Vráble, Slovakia. *In*: J. Kneisel, W. Kirleis, M. Dal Corso, N. Taylor, and V. Tiedtke, eds. *Collapse or continuity? Environment and development of Bronze Age human landscapes*. Bonn: Dr. Rudolf Habelt GmbH, 111-130.

Bátora, J., Eitel, B., Hecht, S., Koch, A., Rassmann, K., Schukraft, G., Winkelmann, K., 2009. Fidvár bei Vráble (Kr. Nitra, Südwestslowakei). Untersuchungen auf einem äneolithisch-frühbronzezeitlichen Siedlungshügel. *Germania: Anzeiger der Römisch-Germanischen Kommission des Deutschen Archäologischen Instituts*, 87 (1), 1-23.

Birkás, M., Jolánkai, M., Gyuricza, C., Percze, A., 2004. Tillage effects on compaction, earthworms and other soil quality indicators in Hungary. *Soil and Tillage Research*, 78(2), 185-196.

Bognár-Kutzián, I., 1963. *The Copper Age cemetery of Tiszapolgár-Basatanya*. Budapest: Akadémiai Kiadó.

Bóna, I., 1992. Bronzezeitlichen Tell-Kulturen in Ungarn. *In*: W. Meier-Arendt and I. Bóna, eds. *Bronzezeit in Ungarn : Forschungen in Tell-Siedlungen an Donau und Theiss. Ausstellungskatalog*. Frankfurt: Stadt Frankfurt Dez. Kultur und Wissenschaft, 9-39.

Bondár, M., 2006. Le chariot en Europe au Chalcolitique récent. *In*: P. Pétrequin, R.-M. Arbogast, A.-M. Pétrequin, S. van Willigen, and M. Bailly, eds. *Premiers chariots, premiers araines. La diffusion de la traction animale en Europe pendant les IVe et IIIe millénaires avant notre ère*. Paris: Centre National de la Recherche Scientifique, 225-237.

Bondár, M., 2008. The paraphernalia of cult life in the Late Copper Age. *Acta Archaeologica Academia Scientiarum Hungaricae*, 59, 171-181.

Bondár, M., 2012. *Prehistoric wagon models in the Carpathian Basin (3500-1500 BC)*. Budapest: Archaeolingua.

Bozán, C., Takács, K., Körösparti, J., Laborczi, A., Túri, N., Pásztor, L., 2018. Integrated spatial assessment of inland excess water hazard on the Great Hungarian Plain. *Land Degradation & Development*, 29(12), 4373-4386.

Chu, W., 2018. The Danube corridor hypothesis and the Carpathian Basin: geological, environmental and archaeological approaches to characterizing Aurignacian dynamics. *Journal of World Prehistory*, 31(2), 117-178.

Dani, J., 2020. Kurgans and their builders: the Great Hungarian Plain at the dawn of the Bronze Age. *Hungarian archaeology*, 9 (summer), 1-20.

Demény, A., Czuppon, G., Siklósi, Zs., Leél-Őssy, S., Lin, K., Shen, C.-C. and Gulyás, K., 2013. Mid-Holocene climate conditions and moisture source variations based on stable H, C and O isotope compositions of speleothems in Hungary. *Quaternary International*, 293, 150-156.

Dixson, A.F. and Dixson, B.J., 2012. Venus figurines of the European Paleolithic: symbols of fertility or attractiveness? *Journal of Anthropology*, 2011, e569120.

Dobos, E., Michéli, E., Baumgardner, M.F., Biehl, L., Helt, T., 2000. Use of combined digital elevation model and satellite radiometric data for regional soil mapping. *Geoderma*, 97, 367-391.

Gábris, G., 1994. Pleistocene evolution of the Danube in the Carpathian Basin. *Terra Nova*, 6, 495-501.

Gardner, A.R., 2002. Neolithic to Copper Age woodland impacts in northeast Hungary? Evidence from the pollen and sediment chemistry records. *The Holocene*, 12(5), 541-553.
Gerling, C., Bánffy, E., Dani, J., Köhler, K., Kulcsár, G., Pike, A.W.G., Szeverényi, V., Heyd, V., 2012. Immigration and transhumance in the Early Bronze Age Carpathian Basin: the occupants of a kurgan. *Antiquity*, 86 (334), 1097-1111.
Gerling, C., Heyd, V., Pike, A., Bánffy, E., Dani, J., Köhler, K., Kulcsár, G., Kaiser, E., Schier, W., 2012. Identifying kurgan graves in eastern Hungary: a burial mound in the light of strontium and oxygen isotope analysis. *In*: E. Kaiser, J. Burger, and W. Schier, eds. *New approaches using stable isotopes and genetics*. Berlin and Boston, MA: De Gruyter, 165-176.
Gogâltan, F., 2008. Fortified Bronze Age tell settlements in the Carpathian Basin: a general overview. *In*: J. Czebreszuk, S. Kadrow, and J. Müller, eds. *Defensive structures from central Europe to the Aegean in the 3rd and 2nd millennia BC*. Poznań and Bonn: Wydawnictwo Poznańskie and Dr. Rudolf Habelt GmbH, 39-56.
Hedges, R., Bentley, R.A., Bickle, P., Cullen, P., Dale, C., Fibiger, L., Hamilton, J., Hofmann, D., Nowell, G., Whittle, A., 2013. The supra-regional perspective. *In:* P. Bickle and A. Whittle, eds., *The first farmers of central Europe: diversity in LBK lifeways.* Oxford Books: Oakville CT.
Heeb, B.S., Szentmiklosi, A., Wiecken, J.M., 2008. Zu den Wallringen von Corneşti-Iarcuri, Jud. Timiş, Rumänien – Forschungsgeschichte und neueste Untersuchungen. *Praehistorische Zeitschrift*, 83 (2), 179-188.
Hertelendi, E., Sümegi, P., Szöör, G., 1992. Geochronologic and paleoclimatic characterization of Quaternary sediments in the Great Hungarian Plain. *Radiocarbon*, 34(3), 833-839.
Horváth, F., Bada, G., Szafián, P., Tari, G., Ádám, A., Cloetingh, S., 2006. *Formation and deformation of the Pannonian Basin: constraints from observational data*. Geological Society Memoirs, 32(1), 191-206.
Jaeger M., Stróżyk, M., Olexa L., Nováek T., 2021. Dating the ladies: spatio-temporal development of the Early Bronze Age cemetery at Nižná Myšľa (Slovakia). *Documenta Praehistorica* 48, 340-353. DOI: 10.4312/dp.48.21
Jaeger, M. and Olexa, L., 2014. The metallurgists from Nižná Myšľa (okr. Košice-okolie/SK): a contribution to the discussion on the metallurgy in defensive settlements of the Otomani-Füzesabony culture. *Archäologisches Korrespondenzblatt*, 44 (2), 163-176.
Jaeger, M., Stróżyk, M., Olexa, L., 2023. Society in transition: cultural change in the Early Bronze Age cemetery at Nižná Myšl'a in the light of absolute chronology. *Radiocarbon*, 65 (1), 135-154.
Jakab, G., Majkut, P., Juhász, I., Gulyás, S., Sümegi, P., Törőcsik, T., 2009. Palaeoclimatic signals and anthropogenic disturbances from the peatbog at Nagybárkány (north Hungary). In: Buczkó, K., Korponai, J., Padisák, J. and Starratt, S.W. eds., *Palaeolimnological proxies as tools of environmental reconstruction in fresh water*. Springer Dordrecht: Dordrecht.
Jakucs, J., Bánffy, E., Oross, K., Voicsek, V., Ramsey, C.B., Dunbar, E., Kromer, B., Bayliss, A., Hofmann, D., Marshall, P., Whittle, A., 2016. Between the Vinča and Linearbandkeramik worlds: the diversity of practices and identities in the 54th-53rd centuries cal BC in southwest Hungary and beyond. *Journal of World Prehistory*, 29 (3), 267-336.
Jarosz, P., Koledin, J., Włodarczak, P., eds., 2021. *Danubian route of the Yamnaya culture: the barrows of Vojvodina*. Budapest: Archaeolingua Alapítvány.
Kasse, C., Bohncke, S.J.P., Vandenberghe, J., Gábris, G., 2010. Fluvial style changes during the last glacial – interglacial transition in the middle Tisza Valley (Hungary). *Proceedings of the Geologists' Association*, 121(2), 180-194.

Kercsmár, Z., Budai, T., Csillag, G., Selmeczi, I., Sztanó, O., Piros, O. eds., 2015. *Surface geology of Hungary: explanatory notes to the geological map of Hungary (1:500 000).* Geological and Geophysical Institute of Hungary: Budapest.

Kiss, T., Hernesz, P., Sümeghy, B., Györgyövics, K., Sipos, G., 2015. The evolution of the Great Hungarian Plain fluvial system – fluvial processes in a subsiding area from the beginning of the Weichselian. *Quaternary International*, 388, 142-155.

Kiss, T., Sümeghy, B., Sipos, G., 2014. Late Quaternary paleodrainage reconstruction of the Maros River alluvial fan. *Geomorphology*, 204, 49-60.

Knipl, I., Sümegi, P., 2012. Life at the interface of two distinct landscapes – relationship of humans and environment in the periphery of the Danube – Tisza interfluve between Hajós and Császártöltés. *Open Geosciences*, 4(3), 1.

Kovács, J., Raucsik, B., Varga, A., Újvári, G., Varga, G., Ottner, F., 2013. Clay mineralogy of red clay deposits from the central Carpathian Basin (Hungary): implications for Plio-Pleistocene chemical weathering and palaeoclimate. *Turkish Journal of Earth Sciences*, 22, 414-426.

Kulcsár, G., 2013. Glimpses of the third millenium BC in the Carpathian Basin. *In*: A. Anders, G. Kalla, V. Kiss, G. Kulcsár, and G. V. Szabó, eds. *Moments in time: papers presented to Pál Raczky on his 60th birthday*. Budapest: L'Harmattan, 643-660.

Laborczi, A., Szatmári, G., Kaposi, A.D., Pásztor, L., 2019. Comparison of soil texture maps synthetized from standard depth layers with directly compiled products. *Geoderma*, 352, 360-372.

Laborczi, A., Szatmári, G., Takács, K., Pásztor, L., 2016. Mapping of topsoil texture in Hungary using classification trees. *Journal of Maps*, 12(5), 999-1009.

Ladányi, Z., Blanka, V., Meyer, B., Mezősi, G., Rakonczai, J., 2015. Multi-indicator sensitivity analysis of climate change effects on landscapes in the Kiskunság National Park, Hungary. *Ecological Indicators*, 58, 8-20.

Mádl-Szőnyi, J., Tóth, J., Pogácsás, G., 2008. Soil and wetland salinization in the framework of the Danube – Tisza interfluve hydrogeologic type section. *Central European Geology*, 51(3), 203-217.

Magyari, E., 2011. Late Quaternary vegetation history in the Hortobágy Steppe and middle Tisza floodplain, NE Hungary. *Studia Botanica Hungarica*, 42, 185-203.

Magyari, E.K., Chapman, J.C., Passmore, D.G., Allen, J.R.M., Huntley, J.P., Huntley, B., 2010. Holocene persistence of wooded steppe in the Great Hungarian Plain. *Journal of Biogeography*, 37(5), 915-935.

Maran, J., 2004a. Kulturkontakte und Wege der Ausbreitung der Wagentechnologie im 4. Jahrtausend v. Chr. *In*: M. Fansa and S. Burmeister, eds. *Rad und Wagen. Der Ursprung einer Innovation. Wagen im Vorderen Orient und Europa*. Mainz: Philipp von Zabern, 429-442.

Maran, J., 2004b. Die Badener Kultur und ihre Räderfahrzeuge. *In*: M. Fansa and S. Burmeister, eds. *Rad und Wagen. Der Ursprung einer Innovation. Wagen im Vorderen Orient und Europa*. Mainz: Philipp von Zabern, 265-282.

Moskal-del Hoyo, M., Lityńska-Zając, M., Raczky, P., Anders, A., Magyari, E.K., 2018. The character of the Atlantic oak woods of the Great Hungarian Plain. *Quaternary International*, 463, 337-351.

Müller, J., 2013. Demographic traces of technological innovation, social change and mobility: from 1 to 8 million Europeans (6000-2000 BCE). *In*: S. Kadrow and P. Włodarczak, eds. *Environment and subsistence – forty years after Janusz Kruk's 'Settlement studies…'*. Rzeszów and Bonn: Mitel and Dr. Rudolf Habelt GmbH, 1-14.

Nádor, A., Thamó-Bozsó, E., Magyari, Á., Babinszki, E., 2007. Fluvial responses to tectonics and climate change during the Late Weichselian in the eastern part of the Pannonian Basin (Hungary). *Sedimentary Geology*, 202(1-2), 174-192.

Négyesi, G., Lóki, J., Buró, B., Bertalan-Balázs, B., Pásztor, L., 2019. Wind erosion researches in Hungary – past, present and future possibilities. *Hungarian Geographical Bulletin*, 223-240.

Novothny, Á., Frechen, M., Horváth, E., 2010. Luminescence dating of periods of sand movement from the Gödöllő Hills, Hungary. *Geomorphology*, 122(3-4), 254-263.
Obreht, I., Zeeden, C., Hambach, U., Veres, D., Marković, S.B., Lehmkuhl, F., 2019. A critical reevaluation of palaeoclimate proxy records from loess in the Carpathian Basin. *Earth-Science Reviews*, 190, 498-520.
Pásztor, L., Körösparti, J., Bozán, C., Laborczi, A., Takács, K., 2015. Spatial risk assessment of hydrological extremities: inland excess water hazard, Szabolcs-Szatmár-Bereg County, Hungary. *Journal of Maps*, 11(4), 636-644.
Pásztor, L., Négyesi, G., Laborczi, A., Kovács, T., László, E., Bihari, Z., 2016. Integrated spatial assessment of wind erosion risk in Hungary. *Natural Hazards and Earth System Sciences*, 16(11), 2421-2432.
Pásztor, L., Szabó, J., Bakacsi, Z., Matus, J., Laborczi, A., 2012. Compilation of 1:50,000 scale digital soil maps for Hungary based on the digital Kreybig soil information system. *Journal of Maps*, 8(3), 215-219.
Petrovszki, J. and Timár, G., 2010. Channel sinuosity of the Körös River system, Hungary/Romania, as possible indicator of the neotectonic activity. *Geomorphology*, 122(3-4), 223-230.
Schofield, R., Thomas, D.S.G., Kirkby, M.J., 2001. Causal processes of soil salinization in Tunisia, Spain and Hungary. *Land Degradation & Development*, 12(2), 163-181.
Sherratt, A., 1983. The development of Neolithic and Copper Age settlement in the Great Hungarian Plain: Part II: site survey and settlement dynamics. *Oxford Journal of Archaeology*, 2(1), 13-41.
Staniuk, R., Wunderlich, M., Meadows, J., Müller-Scheeßel, N., Furholt, M., Cheben, I., 2020. Radiocarbon dating at the LBK and Želizovce settlement site of Vráble. *In*: M. Furholt, I. Cheben, J. Müller, A. Bistáková, M. Wunderlich, and N. Müller-Scheeßel, eds. *Archaeology in the Žitava Valley I: the LBK and Želiezovce settlement site of Vráble*. Leiden: Sidestone Press, 249-264.
Szentmiklosi, A., Heeb, B.S., Heeb, J., Harding, A., Krause, R., Becker, H., 2011. Corneşti-Iarcuri – a Bronze Age town in the Romanian Banat? *Antiquity*, 85 (329), 819-838.
Timár, G., Sümegi, P., Horváth, F., 2005. Late Quaternary dynamics of the Tisza River: evidence of climatic and tectonic controls. *Tectonophysics*, 410(1-4), 97-110.
Tóth, T., Kuti, L., Kabos, L., Pásztor, L., 2001. Use of digitalized hydrogeological maps for evaluation of salt-affected soils of large areas. *Arid Land Research and Management*, 15(4), 329-346.
Uj, B., Nagy, A., Saláta, D., Laborczi, A., Malatinszky, Á., Bakó, G., Danyik, T., Tóth, A., Falusi, E.S., Gyuricza, C., Póti, P., Penksza, K., 2016. Wetland habitats of the Kis-Sárrét 1860-2008 (Körös-Maros National Park, Hungary). *Journal of Maps*, 12(2), 211-221.
Ujházy, K., Gábris, G., Frechen, M., 2003. Ages of periods of sand movement in Hungary determined through luminescence measurements. *Quaternary International*, 111(1), 91-100.
Vandkilde, H., 2014. Cultural perspectives on the beginnings of the Nordic Bronze Age. *Offa*, 67-68, 51-77.
Várallay, G., 1989. Soil degradation processes and their control in Hungary. *Land Degradation and Rehabilitation*, 1, 171-188.
Varga, G., 2011. Similarities among the Plio-Pleistocene terrestrial aeolian dust deposits in the world and in Hungary. *Quaternary International*, 234, 98-108.
Weninger, B., 2020. Barcode seriation and concepts of Gauge Theory: The 14C-chronology of Starčevo, LBK, and early Vinča: formation and transformation of Early Neolithic lifestyles in Europe. *Quaternary International*, 560-561, 20-37.

Whittle, A., Bayliss, A., Barclay, A., Gaydasrka, B., Bánffy, E., Borić, D., Draşovean, F.D., Jakucs, J., Marić, M., Orton, D., Pantović, I., Schier, W., Tasić, N., Linden, M.V., 2016. A Vinča potscape: formal chronological models for the use and development of Vinča ceramics in south-east Europe. *Documenta Praehistorica*, 43, 1-60.

Willis, K.J., Braun, M., Sümegi, P., Tóth, A., 1997. Does soil change cause vegetation change or vice versa? A temporal perspective from Hungary. *Ecology*, 78(3), 740-750.

Willis, K.J., Rudner, E., Sümegi, P., 2000. The full-Glacial forests of central and south-eastern Europe. *Quaternary Research*, 53(2), 203-213.

Włodarczak, P., 2021. Investigations of prehistoric barrows in Bačka – introduction. *In*: P. Jarosz, J. Koledin, and P. Włodarczak, eds. *Danubian route of the Yamnaya culture: the barrows of Vojvodina*. Budapest: Archaeolingua Alapítvány, 9-28.

PART 1.
POPULATION AND SETTLEMENT DYNAMICS

Starčevo – Körös – Criş regional and macro-regional palaeo-demography

Tamara Blagojević, Marko Porčić, Sofija Stefanović

Abstract

The Starčevo – Körös – Criş cultural complex covered a vast geographical region, chronologically spanning from ~6200 cal BCE until ~5300 cal BCE. Its importance lies in being one of the first Early Neolithic manifestations in this part of Europe, which makes its spread farther across the continent crucial. Changes in settlement patterns, material culture and economy through time have been studied. The demographic processes that could have influenced the rate and the speed of the spread have been addressed for particular regions only. In this paper, we present the results of population dynamics reconstructions on the regional, macro-regional and cultural-complex levels using the summed calibrated radiocarbon probability distributions method. The seven regions studied are the territory of Romania; southern Serbia; central Serbia; Vojvodina, also in Serbia; the Great Hungarian Plain; eastern, northern and central Bosnia and Herzegovina; and eastern and northern Croatia. The two macro-regions studied are the central Balkans (covering southern and central Serbia) and Pannonia (covering the remaining five regions). The results indicate distinctive demographic patterns, both on a regional and a macro-regional level, that consist of distinct episodes of population growth and decline. In general, the results are in broad agreement with the predictions of the Neolithic Demographic Transition theory. All regions exhibit significant population growth at the beginning of the Neolithic, with local differences in the later phases.

Keywords: *Early Neolithic demography, radiocarbon chronology, Neolithic demographic transition, Starčevo – Körös – Criş cultural complex*

Introduction

It has been widely attested that the Neolithic was introduced to Europe through processes that included movements of people and ideas originating from the Middle East (Davison *et al.* 2007; Bocquet-Appel *et al.* 2009; Haak *et al.* 2010; Brami and Heyd 2011; Fort 2012; Pinhasi *et al.* 2012; Borić and Price 2013; Gurova and

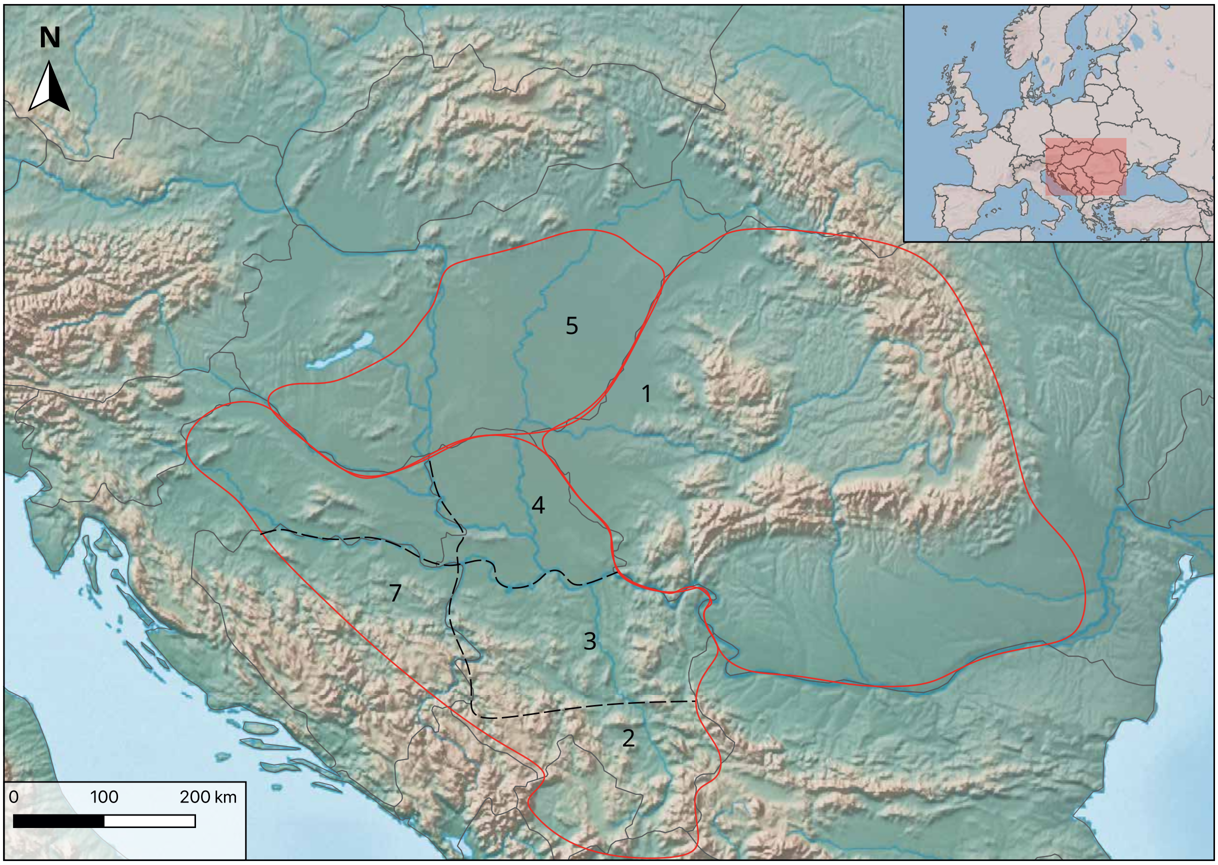

Figure 1. Map representing the territory of the Starčevo – Körös – Criş cultural complex, showing the seven regions as defined in the study: 1. Romania; 2. southern Serbia; 3. central Serbia; 4. Vojvodina, Serbia; 5. Great Hungarian Plain; 6. eastern and northern Croatia; 7. eastern, northern and central Bosnia and Herzegovina. Starčevo: 2, 3, 4, 6, 7, Criş: 1; Körös: 5.

Bonsall 2014; Özdoğan 2014; Mathieson *et al.* 2015; Szécsényi-Nagy *et al.* 2015; Hofmanová *et al.* 2016; Silva and Vander Linden 2017; Mathieson *et al.* 2018). Two main routes have been proposed for its spread following the appearance of the Neolithic in the territory of Greece in the seventh millennium BCE (Perlès *et al.* 2013; Özdoğan 2014). The maritime Mediterranean route led from the territory of Greece to the eastern and western Adriatic coasts, southern France and the Iberian Peninsula. The continental route connected the Balkans to central and eastern Europe. This process took about three thousand years (the Neolithic reached north-western Europe in 4000 BCE) (Price 2000; Bocquet-Appel *et al.* 2009).

Changes in population dynamics are considered to be one of the most distinctive features of Neolithisation, and identifying them will have implications for a better understanding of the complex processes that operated in this important period in human history. The aim of this paper is to reconstruct population dynamics at regional and macro-regional levels, with a particular focus on the territory of Starčevo – Körös – Criş (SKC) cultural complex. The importance of this territory lies in its role in the further spread of the Neolithic, from Greece to the rest of Europe. The macro-regional approach is essential in understanding these processes on a wider geographical scale, while analyses on a regional level will enable the identification of local specifics that could have been caused by various factors (economic, social, environmental).

Starčevo – Körös – Criş cultural complex: Archaeological background

The earliest manifestations of the Neolithic way of life in the territory that covers most of the Balkan Peninsula and parts of the Carpathian Basin are represented by what is termed the SKC cultural complex. This heterogeneous complex included areas on the right bank of the River Danube (Starčevo culture); the Tisza Valley, within the Great Hungarian Plain (Körös culture); and Transylvania (Criş culture), *i.e.* the territory of modern-day Serbia; northern, eastern and central Bosnia and Herzegovina; eastern and northern Croatia; Romania; and south-eastern Hungary (Garašanin 1979; 1982; Bailey 2000; Mester and Rácz 2010) (Fig. 1). The most common characteristic of the complex is the predominance of single-layered settlements with pit and semi-pit features, located on river terraces, slopes near springs or streams, or mild elevations above the wetlands and swamps (Garašanin 1979; Kosse 1979; Garašanin 1982; Bogdanović *et al.* 1988; Greenfield and Draşovean 1994; Bailey 2000). The economy was mostly based on herding, with cattle and ovicaprines being the prevailing domestic species at most of the sites (*e.g.* Clason 1980; Bökönyi 1988; Blažić 2005; Greenfield *et al.* 2014; Марковић *et al.* 2018). All these features have been interpreted as indicators of the mobile economy and way of life of the first Neolithic communities (Greenfield and Jongsma 2008; Greenfield *et al.* 2014).

The earliest radiocarbon dates come from the Starčevo culture of the central Balkans. Based on the earliest dates from the site of Blagotin, Serbia, and the first appearance of pottery in Mesolithic contexts at the Danube Gorges sites (Garašanin and Radovanović 2001; Whittle *et al.* 2002; Borić 2009; 2011), its beginning was conventionally dated to ~6200 cal BCE. Recent studies have yielded new AMS dates that indicate the possibility of an even earlier beginning of the Starčevo culture, placing it at around 6250 cal BCE (Porčić *et al.* 2021). The Starčevo culture existed until around 5300 cal BCE. It has been proposed that it spread from south to north and that the speed of the spread was faster than the estimated continental average (of 1-2%) (Ammerman and Cavalli-Sforza 1984; Bocquet-Appel 2002; Bocquet-Appel and Naji 2006; Bocquet-Appel 2013), with the possibility of sporadic leap-frog events (Porčić *et al.* 2020; Blagojević 2022).

In the territory of Romania, the Criş culture lasted from around 5900 until around 5100 cal BCE (Ehrich and Bankoff 1990; Biagi and Spataro 2005; Greenfield and Jongsma 2008). The distribution of sites indicates that the route of the spread included major river valleys, such as Mureș, Olt, Danube and Someș (Luca *et al.* 2011). It is considered that this process was very fast, including the almost simultaneous occurrence of the earliest Neolithic manifestations over a vast geographical space (Biagi and Spataro 2005).

In the territory of Hungary, two Early Neolithic cultures were defined: Starčevo, in the southern parts of Transdanubia, and Körös, on the Great Hungarian Plain. The main routes of the spread were connected to major river valleys, of the Danube, Tisza, Körös, Maros and Berettyó (Bánffy *et al.* 2007; Paluch 2012). Radiocarbon dates from sites located on the southernmost parts of the Great Hungarian Plain indicate that the beginning of the Körös culture was around 6000 cal BCE (Oross and Siklósi 2012). A dense concentration of the Körös culture sites (more than 1000 sites currently known) has been detected in the Great Hungarian Plain area, while the Starčevo culture sites are less represented. The great site density in this area is probably a consequence of the highly favourable environmental conditions, *i.e.* fertile soil on a vast territory with minimal latitudinal oscillations and a dense river network with occasional flooding events (Kalicz *et al.* 1998; Bánffy *et al.* 2007; Paluch 2012).

The earliest Neolithic in the territory of Bosnia and Herzegovina is characterised by two distinct Neolithic cultures. The Starčevo culture was defined in the continental area, while the Impresso culture is characteristic for the Adriatic region (Garašanin 1979;

Tasić 2007; Vander Linden *et al.* 2014). The duration of the Starčevo culture was determined to be between ~5900 and ~5300 cal BCE, based on the modelling of the available radiocarbon dates (Vander Linden *et al.* 2014). Unlike neighbouring regions, which have multiple Early Neolithic sites, in this area only two Early Neolithic sites with clearly defined Starčevo horizons have been investigated: Obre I and Gornja Tuzla. Another Early Neolithic site from central Bosnia is Arnautovići, where pottery with an admixture of Starčevo and Impresso motifs has been discovered (Gimbutas 1974; Pinhasi *et al.* 2005; Vander Linden *et al.* 2014).

The Starčevo culture in the territory of modern-day Croatia lasted between ~6000 and ~5300 cal BCE, with the earliest dates coming from the site of Sopot, located in the northern part of Croatia (Botić 2016). The emergence and spread of the Starčevo culture are linked to the river flows of the Sava, Drava and Danube. The presumed direction of expansion within this territory is along the south-east – north-west axis, and it includes the first manifestation of the Early Neolithic in western Syrmia and eastern Slavonia. From these areas, the Neolithic spread to the Baranya region, to western Slavonia, and farther along the Drava Valley (Botić 2016).

The aim of the research

In the past several years, the question of population dynamics of the first Neolithic communities in the territory of the SKC cultural complex has been tackled in several different studies. These studies have mostly concentrated on reconstructing the changes in population dynamics in separate regions (predominantly the territory of Serbia) by using the summed calibrated radiocarbon probability distributions (SCPD) method, within the framework of the Neolithic demographic transition theory (NDT; Porčić *et al.* 2016; Blagojević *et al.* 2017; Porčić *et al.* 2021; Blagojević 2022). A recent PhD dissertation included SCPD analysis within separate regions in the territory that mostly covers the SKC cultural complex (Blagojević 2022). The results of all these studies have enabled the identification of demographic patterns that consist of distinct episodes of population growth and decline, resembling a boom-and-bust pattern (Shennan *et al.* 2013; Timpson *et al.* 2014; Crema *et al.* 2016; Silva and Vander Linden 2017), with certain local specifics. The speed of spread has also been estimated, indicating faster rates at the regional level compared with the continental level (Porčić *et al.* 2020; Blagojević 2022).

The aim of this paper is to define the most prominent patterns in the population dynamics at the regional and macro-regional levels in the territory of SKC cultural complex by using the SCPD method within the theoretical framework of the NDT.

The main assumptions of the NDT (Bocquet-Appel 2002; 2008; Bocquet-Appel and Bar-Yosef 2008; Bocquet-Appel *et al.* 2008; 2011a; 2011b; 2013) are used as the basis for defining the expected pattern of demographic changes. Specifically, an episode of pronounced population growth, with an average continental rate of 1-2%, is expected to be detected at the beginning of the Neolithic in all regions, as defined within the first stage of the NDT (Bocquet-Appel 2002; Bocquet-Appel and Naji 2006; Bocquet-Appel 2008; 2013). This stage is characterised by population growth caused by general changes in people's way of life, but particularly by changes in subsistence and mobility patterns that enabled a rise in fertility (Buikstra *et al.* 1986; Bocquet-Appel 2002; Valeggia and Ellison 2004; Bocquet-Appel and Bar-Yosef 2008; de Becdelièvre *et al.* 2015). The effects of these changes have been defined and explained within the Relative Metabolic Load model (Valeggia and Ellison 2004; Bocquet-Appel 2008), which represents the core of the NDT. This model explains the effects of changes in diet and food availability on female fertility, most prominently, the higher intake of carbohydrates due to cereal consumption and their influence on postpartum energy rebound, which would have allowed mothers to have babies at shorter time intervals, consequently increasing the overall number of births (Binford

and Chasko 1976; Bocquet-Appel and Bar-Yosef 2008). It also incorporates changes in residential mobility and the influence of increased sedentism and architectural innovations.

The expected pattern also includes an episode of decline in population size due to mechanisms that led to a rise in mortality, which is part of the second stage of the NDT (Bocquet-Appel 2008). Considering the fact that population growth stopped at one point during the NDT, it is assumed that this happened due to an increase in mortality. Besides leading to a growth in fertility, the Neolithic way of life affected the quality of life in general. Numerous studies have shown that the health status of Neolithic populations was worse compared to that of their predecessors, the Mesolithic hunter-gatherer communities (Cohen 2008; Wittwer-Backofen and Tomo 2008; Papathanasiou 2011; Jovanović 2017; Jovanović *et al.* 2021). The rise in mortality, especially among infants, is considered to be the result of multiple factors, including the emergence of new diseases (especially zoonoses), the lack of drinking water in settlements and poor hygiene. Moreover, the introduction of cereals to the diet reduced the intake of important nutrients, such as proteins, iron and vitamin C. By shortening the breastfeeding period, the resistance of children to disease was also affected, since the intake of important antibodies, vitamins and minerals from the breastmilk was stopped earlier in childhood (Cohen 2008; Wittwer-Backofen and Tomo 2008; Papathanasiou 2011; Jovanović 2017; Jovanović *et al.* 2021). As a result of these processes, the rise in mortality caught up with the rise in fertility after a certain period. In other words, the population stopped growing and became stationary; its growth rate equalled zero, and its constant size was maintained through time (Ryder 1975).

Materials and methods

The method applied for the population dynamics reconstruction is the SCPD method, which was developed on the basis of the concept defined by Rick (1987): 'dates as data'. The basic assumption of the method is that the amount of material remains that a population produces over a certain time interval will be directly proportional to the population size from that time interval. Therefore, the change in the frequency of radiocarbon dates should reflect general changes in population size. It should be emphasised that these changes are observed on a population level and a wider timescale (hundreds of years). The SCPD method has been applied to data from various regions in Europe (Shennan *et al.* 2013; Timpson *et al.* 2014; Porčić *et al.* 2016; Blagojević *et al.* 2017; Silva and Vander Linden 2017; Porčić *et al.* 2021; Blagojević 2022) and elsewhere in the world (Lesure 2008; Lesure *et al.* 2014; Crema *et al.* 2016), and it has been used successfully to detect changes in population size at the continental level as well as at the level of individual regions. Moreover, the results of the SCPD analysis support the hypothesis of the NDT, which posits that there is population growth during the first phase of neolithisation (Shennan *et al.* 2013; Timpson *et al.* 2014; Crema *et al.* 2016; Silva and Vander Linden 2017). This method has enabled the detection of very similar fluctuations in population dynamics in most of the researched regions. An abrupt rise in population size at the beginning of the Neolithic, followed by a brief period of stabilisation and a subsequent decline in population size, are indicative of the observed boom-and-bust patterns (Shennan *et al.* 2013; Timpson *et al.* 2014; Crema *et al.* 2016; Silva and Vander Linden 2017).

The results of the SCPD method application can be affected by several different sources of bias: research bias; sample bias; calibration curve effects; and taphonomic bias (Williams 2012; Shennan *et al.* 2013; Timpson *et al.* 2014). One of the most common criticisms of the SCPD method is related to the sample size, *i.e.*

whether the method can produce a realistic estimate of changes in the population size if the sample is not large enough (Williams 2012; Contreras and Meadows 2014). Sample size certainly plays a significant role, because in the case of large samples, and according to the law of large numbers, the biases that exist in individual cases will cancel each other out. Another type of research bias is related to cases where there are many radiocarbon dates from a single site. In these cases, the binning (or grouping) of dates is performed in such a way that each new bin is formed based on the predefined chronological difference between the bins. This difference is usually 100 or 200 years (Shennan *et al.* 2013; Timpson *et al.* 2014). In this research, it was set to 100 years. This procedure enables defining artificial phases within the site, with every 'phase' containing all the dates that are no more than 100 years apart and ensures that each obtained 'phase' has equal weight in generating the final population curve. After binning, the effective sample size is smaller in relation to the total number of dates because now the basic 'unit of measurement' is not each date individually but each of the bins.

The calibration curve effects primarily refer to the shape of the probability distributions of individual calibrated values, which are directly affected by the shape of the calibration curve in a given time interval (Williams 2012; Weninger *et al.* 2015; Crema and Bevan 2020). Taphonomic bias refers to the effects of taphonomic processes on the formation of the archaeological record. It is manifested by the loss of information through time, following an exponential trend.

Generating the population curve includes generating the distribution of the SCPD curve from the null model. This procedure is done by random sampling of the calendar dates from specific time intervals. The determination of these time intervals is based on the probabilities predicted by the null model. The number of calendar dates that enter the model is equal to the empirical number of dates (or groups of dates, *i.e.* bins, if the binning procedure was performed). The next step is recalibration, *i.e.* making the calibrated dates uncalibrated again by simulation. More precisely, possible uncalibrated values that could have produced the obtained calibrated values are being simulated based on the standard errors of the empirical sample. This way, all the uncertainties regarding the sample size and the calibration curve effects are taken into account (Crema and Bevan 2020). After that, the calibrated radiocarbon probability distributions are summed, and one of the possible SCPD results is generated from the null model. The procedure is repeated a large number of times (in the case of this study, a total of 10 000 iterations were performed for every single analysis) to generate an SCPD curve from the null model. In this study, the uniform model was used as a null model, which is the model used for addressing the statistical significance of the changes observed in the empirical data. This model predicts a constant population size through time, making the changes on the empirical curve easier to identify.

Another important procedure that should be explained is the normalisation procedure. It is a mathematical procedure that enables the probabilities of individual calibrated years to add up to a value of 1. In this procedure, distributions of individual dates are normalised before they are summed, because the normalisation ensures equal treatment of all the dates included in the analysis. The sums of the bins are also normalised before the SCPD curve is generated. The disadvantage of using the normalisation procedure is that it can produce artificial peaks on the curve, which usually occur at a predictable rate in parts where the calibration curve is steep. This problem has been addressed in several different studies (Weninger *et al.* 2015; Bevan *et al.* 2017; Crema and Bevan 2020). These studies have shown that even though differences can be observed between curves obtained with and without normalisation, applying normalisation did not interfere with the general trend in population dynamics. In this research, all the analyses were performed both with and without the normalisation procedure.

The main indicators of the changes in population size are the changes observed on the SCPD curve. The graph that represents the results of the SCPD analysis contains the empirical curve, which represents the population curve generated from the empirical data; the null model curve; and the confidence interval (CI) of the null model curve. As a next step, changes in the population size observed on the curve should be tested. This process involves a comparison between the empirical curve and simulated values or, more precisely, their 95% CI. Statistically significant values will be the ones that exceed the 95% confidence interval limits. If the values exceed the higher end of the limit, they would be interpreted as statistically significant population growth. Similarly, if the values go below the lower end of the 95% confidence interval limit, they are considered indicative of a statistically significant decline in population size. The value that indicates whether the statistically significant deviation for the entire time series is present was also used. That is the global p-value (or global significance), which is generated by comparing the total area of the empirical and simulated SCPD values that exceed the 95% confidence interval limits (Crema and Bevan 2020).

In this study, a standard SCPD method that accounts for research bias, changes in the calibration curve, and taphonomy was used (Shennan *et al.* 2013; Timpson *et al.* 2014). The test for statistical significance was also incorporated into the method. Additional testing of the difference between two points on the resulting SCPD curve has been performed in certain cases, as formulated by Edinborough and colleagues (Edinborough *et al.* 2017).

The method was implemented in the program R for statistical computing (R Core Team 2019), using the software package rcarbon (Bevan and Crema 2018; Crema and Bevan 2020), with the latest (IntCal20) calibration curve (Reimer *et al.* 2020).

The seven regions defined in this study are 1. Romania (58 dates from 15 sites); 2. southern Serbia (40 dates from 8 sites); 3. central Serbia (108 dates from 19 sites); 4. Vojvodina, Serbia (148 dates from 25 sites); 5. the Great Hungarian Plain, in southern Hungary (144 dates from 22 sites); 6. eastern, northern and central Bosnia and Herzegovina (11 dates from 4 sites); and 7. eastern and northern Croatia (41 dates from 11 sites) (Appendix 1). The two macro-regions defined in this study are the central Balkans (covering southern and central Serbia – 148 dates from 27 sites) and Pannonia (covering the territory of Romania, the Great Hungarian Plain, Vojvodina and eastern and northern Croatia – 402 dates from 77 sites) (Fig. 1). A separate SCPD analysis has been performed for six of the seven regions defined; the territory of Bosnia and Herzegovina was omitted due to its small sample size. Separate SCPD analyses were also performed for the two macro-regions and for the entire complex (550 dates from 104 sites) (Appendix 1). Both conventional and AMS dates were used, with the upper limit for the standard error being set at 100 years in order to ensure a higher level of precision.

This study did not include radiocarbon dates from the Danube Gorges (from either the Serbian or the Romanian side). The Danube Gorges is one of the few areas where the existence of indigenous hunter-fisher-gatherer populations and their interactions with first Neolithic communities have been confirmed. These interactions led to distinct and more gradual processes of accepting and incorporating different aspects of the Neolithic way of life. Therefore, this region can be considered a rather isolated area within the processes of neolithisation compared to neighbouring regions, with a different set of research questions that could be defined. Changes in population dynamics in the Danube Gorges during the Mesolithic, Transformation and Early Neolithic periods have been thoroughly discussed in other studies (Bonsall *et al.* 2015; Porčić and Nikolić 2016; de Becdelièvre *et al.* 2021; Blagojević 2022).

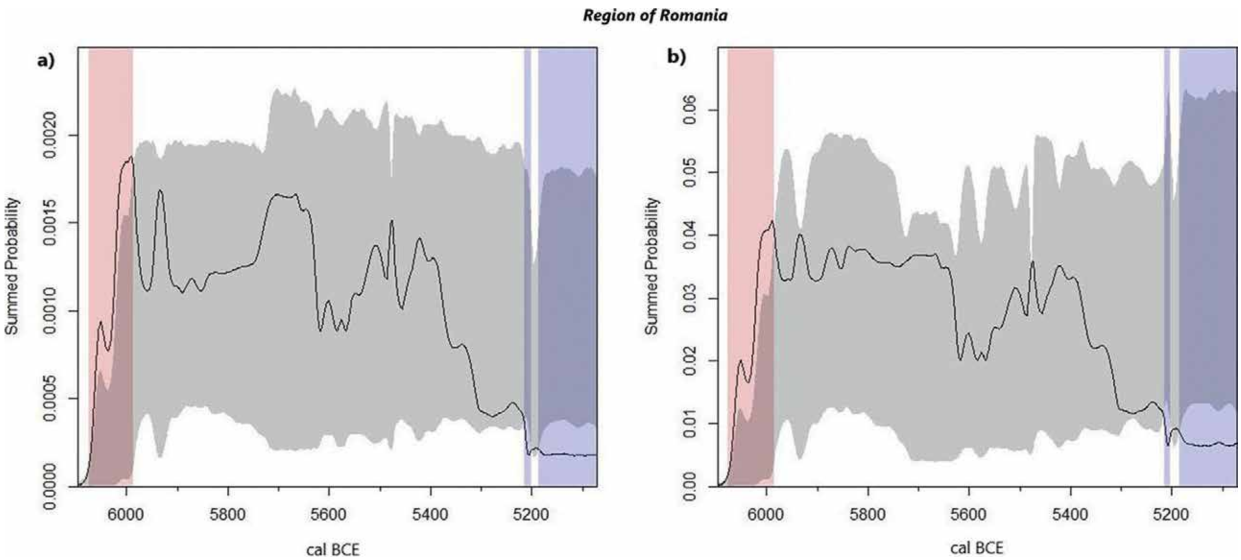

Figure 2. The results of the SCPD analysis on the sample from the region of Romania: a) with normalisation (p=0.016); and b) without normalisation (p=0.005). The black line represents the empirical SCPD curve, obtained on the radiocarbon dates (N=58, number of bins=30); the CI are represented with the grey area and significant deviations are represented with colours – red for the significant increase and blue for the significant decrease on the curve. The figure was produced by T. Blagojević in the R programming language using the rcarbon package (Bevan and Crema 2018; Crema and Bevan 2020).

Results and discussion

Region of Romania

The results of the SCPD analysis for the region of Romania are statistically significant, and the observed pattern indicates the existence of fluctuations on the curve (Fig. 2). Except for the initial growth, which peaked around 6000 cal BCE, all fluctuations fall within the 95% CI limits. The possibility of an edge effect should not be excluded in this case, since the peak emerges abruptly at the very beginning of the interval. The results of the analysis without the normalisation procedure differ in some details. Fluctuations on the curve are generally less pronounced, but the drop around 5650 cal BCE is more prominent. This drop is followed by a gradual rise on a curve between 5550 and 5450 cal BCE. The results indicate that, based on the currently available data, no significant changes in the population dynamics during the Early Neolithic can be observed. However, it should be kept in mind that, even though the results are statistically significant, the sample size is low (58 radiocarbon dates, 30 bins). Therefore, these results should be considered as only a preliminary indicator and a starting point for further research, which will include other (archaeological and anthropological) indicators of changes in population dynamics. Preliminary results of the growth rate estimations for the observed episode of growth show values that are higher than 2.3% (Blagojević 2022), which is higher than the continental average predicted by the NDT (of 1-2%) (Bocquet-Appel 2002; Bocquet-Appel and Naji 2006; Bocquet-Appel 2013). Combined, these data could support the hypothesis of the fast spread of the first Neolithic settlers. A population influx to the previously uninhabited area, combined with the rise in fertility due to the NDT mechanisms, would produce a significant and abrupt increase on the SCPD curve, as well as high growth rates.

Region of the Great Hungarian Plain

In the region of the Great Hungarian Plain, a continual rise of the curve begins as early as around 6000 cal BCE, but it is most pronounced somewhere between 5800 and 5550 cal BCE, reaching its peak around 5750 cal BCE (Fig. 3). This episode of increase covers a somewhat longer interval when the analysis is performed without the normalisation procedure. The general pattern of population

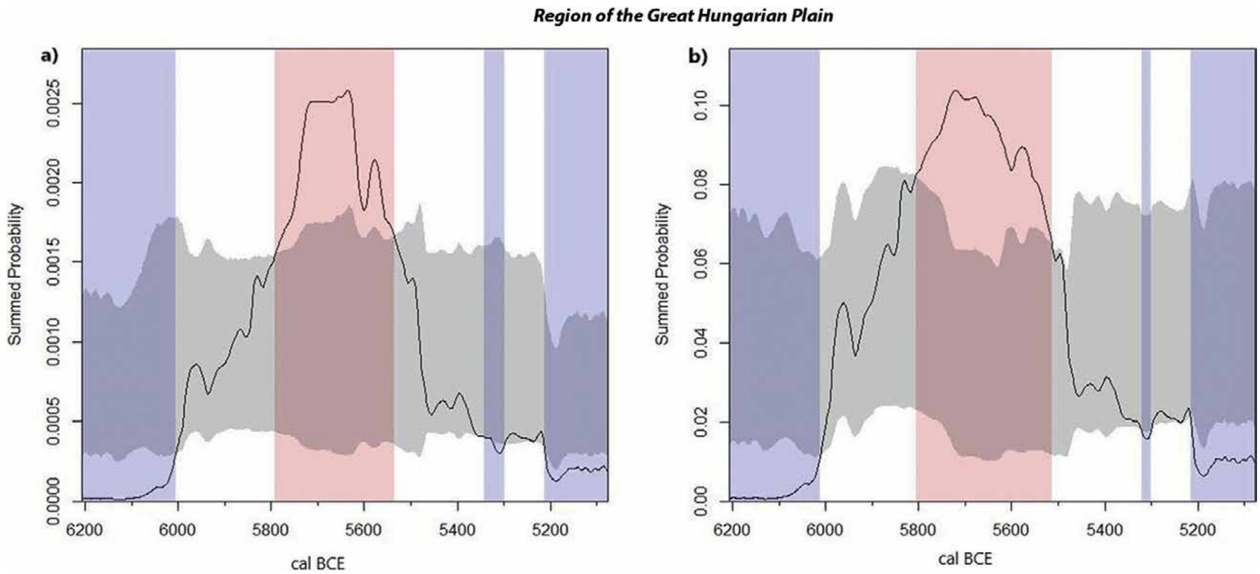

Figure 3. The results of the SCPD analysis on the sample from the region of Great Hungarian Plain: a) with normalisation (p< 0.001); and b) without normalisation (p< 0.001). The black line represents the empirical SCPD curve, obtained on the radiocarbon dates (N=144, number of bins=55); the CI are represented with the grey area and significant deviations are represented with colours – red for the significant increase and blue for the significant decrease on the curve. The figure was produced by T. Blagojević in the R programming language using the rcarbon package (Bevan and Crema 2018; Crema and Bevan 2020).

dynamics corresponds with the results obtained in the previous study, with both indicating a rise in population size at the beginning of the Neolithic, interpreted as the signal of the first phase of the NDT (Blagojević *et al.* 2017). Estimated growth rate values for this region are higher than the continental average (higher than 2.6%; Blagojević 2022). The timing of the increase in population size corresponds well with the drop observed on the population curve for the territory of Serbia (Blagojević *et al.* 2017; Porčić *et al.* 2021; Blagojević 2022). The explanation of the boom-and-bust patterns on the continental level, proposed by the travelling wave-front model (Silva and Vander Linden 2017), could be applied to the regions of the central Balkans and the Great Hungarian Plain. This model proposes that the initial episodes of growth could be explained by the arrival of the new population, while the episodes of decline represent the signal of the migrating population moving to the previously uninhabited area (Silva and Vander Linden 2017). In this case, considering the reconstructed route of expansion, the chronology and the timing of different episodes of growth and decline on the SCPD curves in both regions, it could be argued that the observed patterns are connected, as has already been suggested in previous studies (Porčić *et al.* 2021; Blagojević 2022).

Region of eastern and northern Croatia

The results obtained for the region of eastern and northern Croatia were not statistically significant for the analysis with the normalisation procedure. They were, however, significant when this procedure was not applied (Fig. 4). The resulting pattern can therefore only be considered in terms of gaining a preliminary picture of changes in population dynamics. It indicates the beginning of fluctuations on a curve somewhere before 6000 cal BCE, but the real rise is observed around 5850 cal BCE, reaching its peak around 5750 cal BCE. In the case of the analysis with the normalisation procedure, a small drop on a curve can be observed around 5850 cal BCE. This drop goes below the 95% CI limits, and it is followed by growth on a curve, with the previously mentioned peak around 5750 cal BCE. The specific point-to-point test was performed between the drop (marked as point A on the curve) and the peak (marked as point B on the curve) to check for the significance of the growth. The result indicates that the growth in this interval is statistically significant (Fig. 4). It can be assumed that this kind of result is a consequence of the small effective sample size. Considering all the above, the pattern observed on the SCPD curve should only be seen as a broad and preliminary indicator of changes in population dynamics.

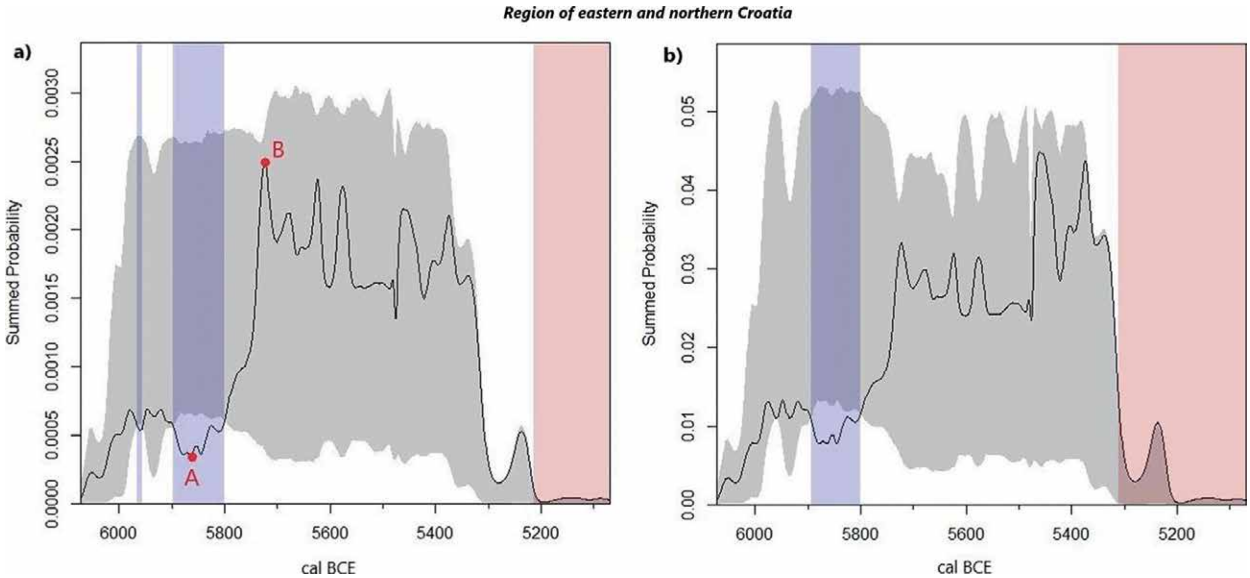

Figure 4. The results of the SCPD analysis on the sample from the region of eastern and northern Croatia: a) with normalisation (p=0.06); and b) without normalisation (p=0.02). The black line represents the empirical SCPD curve, obtained on the radiocarbon dates (N=41, number of bins=20); the CI are represented with the grey area and significant deviations are represented with colours – red for the significant increase and blue for the significant decrease on the curve. Points A and B represent the points on the curve used in the point-to-point test (p=0.02). The figure was produced by T. Blagojević in the R programming language using the rcarbon package (Bevan and Crema 2018; Crema and Bevan 2020).

Region of southern Serbia

For the region of southern Serbia, the results of the SCPD analysis are not statistically significant, most probably due to the small effective sample size (Fig. 5). The curve indicates the beginning of population growth occurred around 6250 cal BCE, with the peak around 6100 cal BCE. Somewhere around 6000 cal BCE, a drop can be observed, and the curve reaches its lowest point between 5900 and 5850 cal BCE. Very soon after, around 5800 cal BCE, a gradual rise can be seen, reaching its peak around 5650 cal BCE. Since these changes on the curve are located inside the confidence interval limits, the specific point-to-point test was conducted between the peak of the first growth (marked as point A), and the following drop on the curve (marked as point B). The results indicate a statistically significant change in the curve (Fig. 5). The test between points B and C (the peak of the second rise on the curve) also indicates a statistically significant change (Fig. 5). Similar results have also been obtained on the curve without normalisation.

The pattern observed for the territory of southern Serbia is in accordance with the previous results of the population dynamics reconstruction for the entire central Balkans territory (Porčić *et al.* 2016; 2021; Blagojević 2022). The first peak, around 6100 cal BCE, corresponds well with the reconstructed south-to-north direction of the spread of the Neolithic (Whittle *et al.* 2002; Blagojević 2022), indicating the influx of a new population, *i.e.* the arrival of the first farmers in the region of southern Serbia at the beginning of the Neolithic. This is also supported by the estimated local speed of the spread of the Neolithic. The inverse distance weighting method was used in previous research to estimate the local speeds of the spread (Blagojević 2022), primarily to gain insight into the inter-regional rate of the spread within the central Balkans territory. The average speed of the spread was 2.13 km/year, which is higher than the continental average (~1 km/year; Ammerman and Cavalli-Sforza 1984), with particularly high values calculated for the southern region (more than 4 km/year; Blagojević 2022).

The second peak (around 5650 cal BCE) also corresponds well with the general pattern for the entire territory, possibly indicating in-situ population growth induced by the NDT mechanisms after the initial consolidation of the Neolithic way of life (Porčić *et al.* 2016; 2021; Blagojević 2022). One of the biggest problems regarding the interpretation of the results is the small number of Early Neolithic sites that were systematically excavated. As a result, this region has the fewest available radiocarbon dates, making all the observed results and patterns insufficiently supported and vague at this level of research.

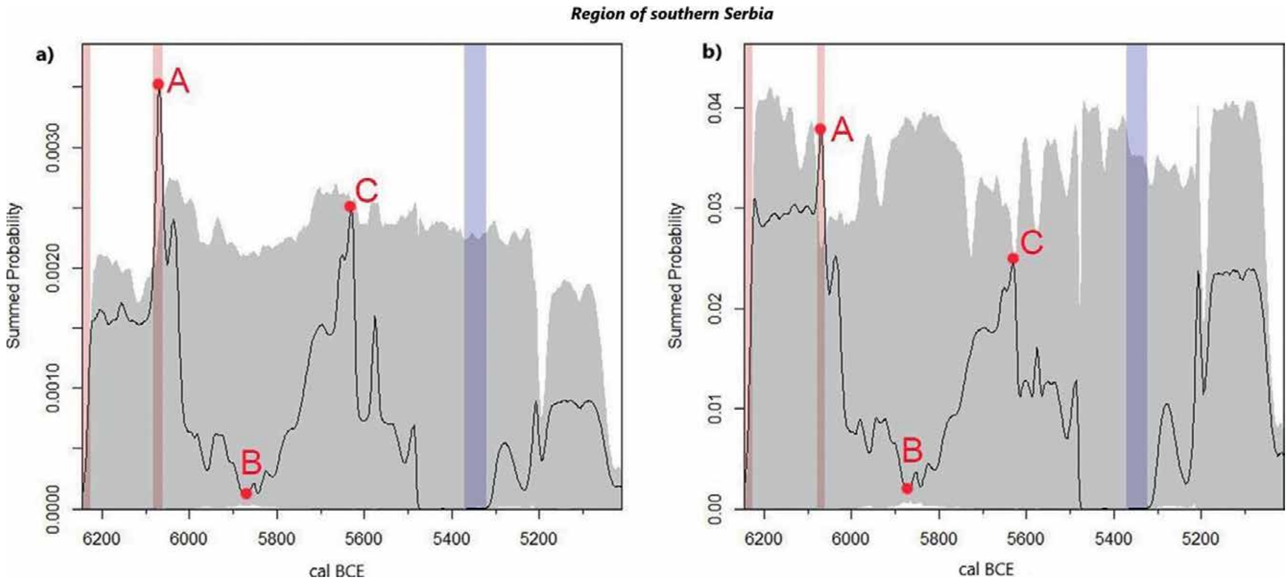

Figure 5. The results of the SCPD analysis on the sample from the region of southern Serbia: a) with normalisation (p=0.123); and b) without normalisation (p=0.143). The black line represents the empirical SCPD curve, obtained on the radiocarbon dates (N=40, number of bins=17); the CI are represented with the grey area and significant deviations are represented with colours – red for the significant increase and blue for the significant decrease on the curve. Points A, B and C represent the points on the curve used in the point-to-point test a) with normalisation (p< 0.001 for the difference between A and B; p=0.024 for the difference between B and C); and b) without normalisation (p=0.001 for the difference between A and B; p=0.021 for the difference between B and C). The figure was produced by T. Blagojević in the R programming language using the rcarbon package (Bevan and Crema 2018; Crema and Bevan 2020).

Region of central Serbia

The results for the region of central Serbia indicate a similar pattern to that seen for the southern Serbia sample (Fig. 6). In this case, the results are statistically significant, but the effective sample size is also larger. The pattern is also characterised by two episodes of growth and one episode of decline on the curve. In this case, the growth starts around the same time as in southern Serbia (~6250 cal BCE) but lasts longer; the drop is observed around 5750 cal BCE. It is followed by a second episode of growth, with a peak around 5650 cal BCE. Apart from the initial growth, the other two distinctive episodes of change are located inside the 95% CI limits, which is why the point-to-point test was conducted. The results are statistically significant for the difference between the first growth and the drop (points A and B on the curve), both for the analysis with the normalisation procedure and for the analysis without it (Fig. 6). The results of the point-to-point test are not significant for the drop in the second episode of growth (points B and C on the curve) when normalisation is applied (Fig. 6), but they are significant when normalisation is not applied (Fig. 6).

The almost simultaneous population growth in central and southern Serbia could be another indicator of the quick arrival of the first Neolithic farmers. This assumption could be supported by the previously mentioned estimated local spread speeds (Blagojević 2022).

The region of Vojvodina

The largest sample from the territory of Serbia comes from the region of Vojvodina, and the overall pattern is statistically significant (Fig. 7). The rise on the curve starts around 6100 cal BCE, with the peak being reached around 6000 cal BCE, but staying within the 95% CI limits. The specific point-to-point test has shown that this rise is not significant (Fig. 7). After the fluctuations that follow, a new rise can be observed around 5750 cal BCE, with a peak around 5650 cal BCE. Another drop on the curve follows, reaching its lowest point ~5450 cal BCE. In this case, the population growth is more gradual than is observed for the southern and central Serbia regions, which can be explained by the proposed south-to-north direction of the Neolithic front in this territory (Whittle *et al.* 2002; Blagojević 2022). This would indicate that the Neolithic farmers reached the northern region after some time of adaptation and consolidation of the Neolithic practices farther south.

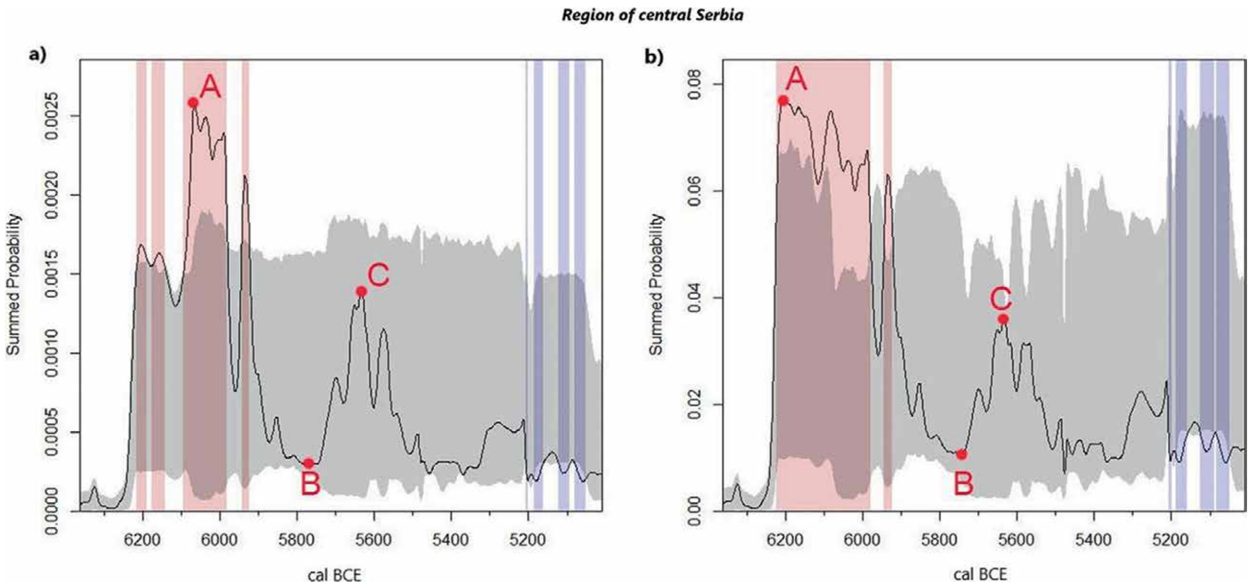

Figure 6. The results of the SCPD analysis on the sample from the region of central Serbia: a) with normalisation (p=0.015); and b) without normalisation (p=0.002). The black line represents the empirical SCPD curve, obtained on the radiocarbon dates (N=108, number of bins=39); the CI are represented with the grey area and significant deviations are represented with colours – red for the significant increase and blue for the significant decrease on the curve. Points A, B and C represent the points on the curve used in the point-to-point test a) with normalisation (p< 0.001 for the difference between A and B); p=0.067 for the difference between B and C); and b) without normalisation (p=0.006 for the difference between A and B; p=0.034 for the difference between B and C). The figure was produced by T. Blagojević in the R programming language using the rcarbon package (Bevan and Crema 2018; Crema and Bevan 2020).

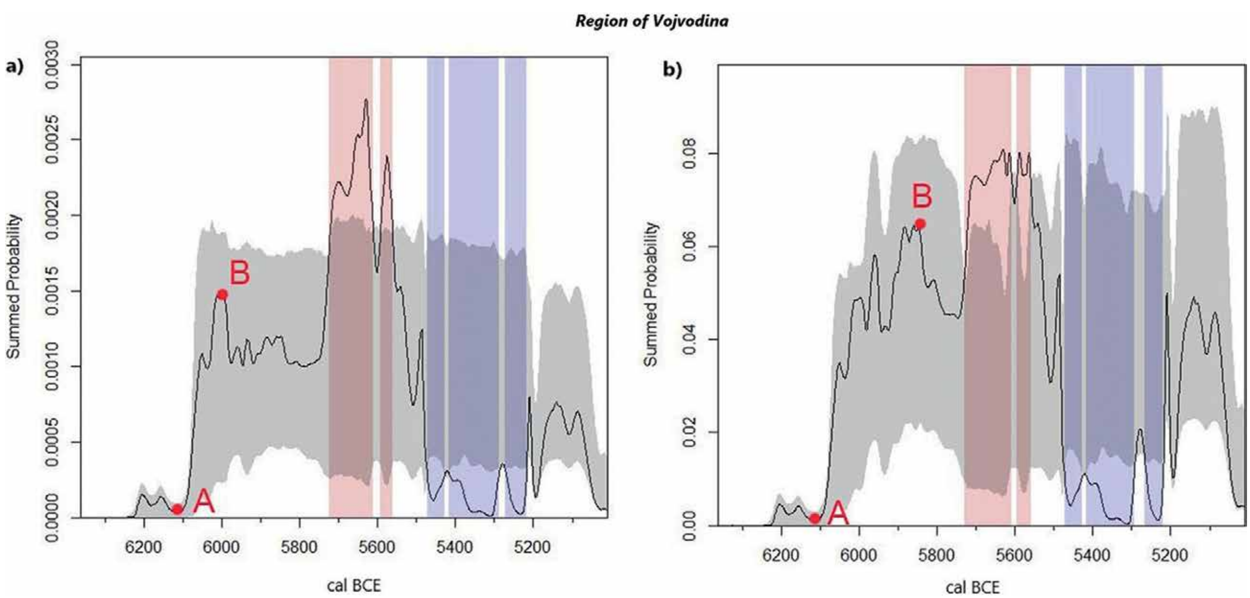

Figure 7. The results of the SCPD analysis on the sample from the region of Vojvodina: a) with normalisation (p=0.004); and b) without normalisation (p=0.004). The black line represents the empirical SCPD curve, obtained on the radiocarbon dates (N=148, number of bins=46); the CI are represented with the grey area and significant deviations are represented with colours – red for the significant increase and blue for the significant decrease on the curve. Points A and B represent the points on the curve used in the point-to-point test: a) with normalisation (p=0.232); and b) without normalisation (p=0.354). The figure was produced by T. Blagojević in the R programming language using the rcarbon package (Bevan and Crema 2018; Crema and Bevan 2020).

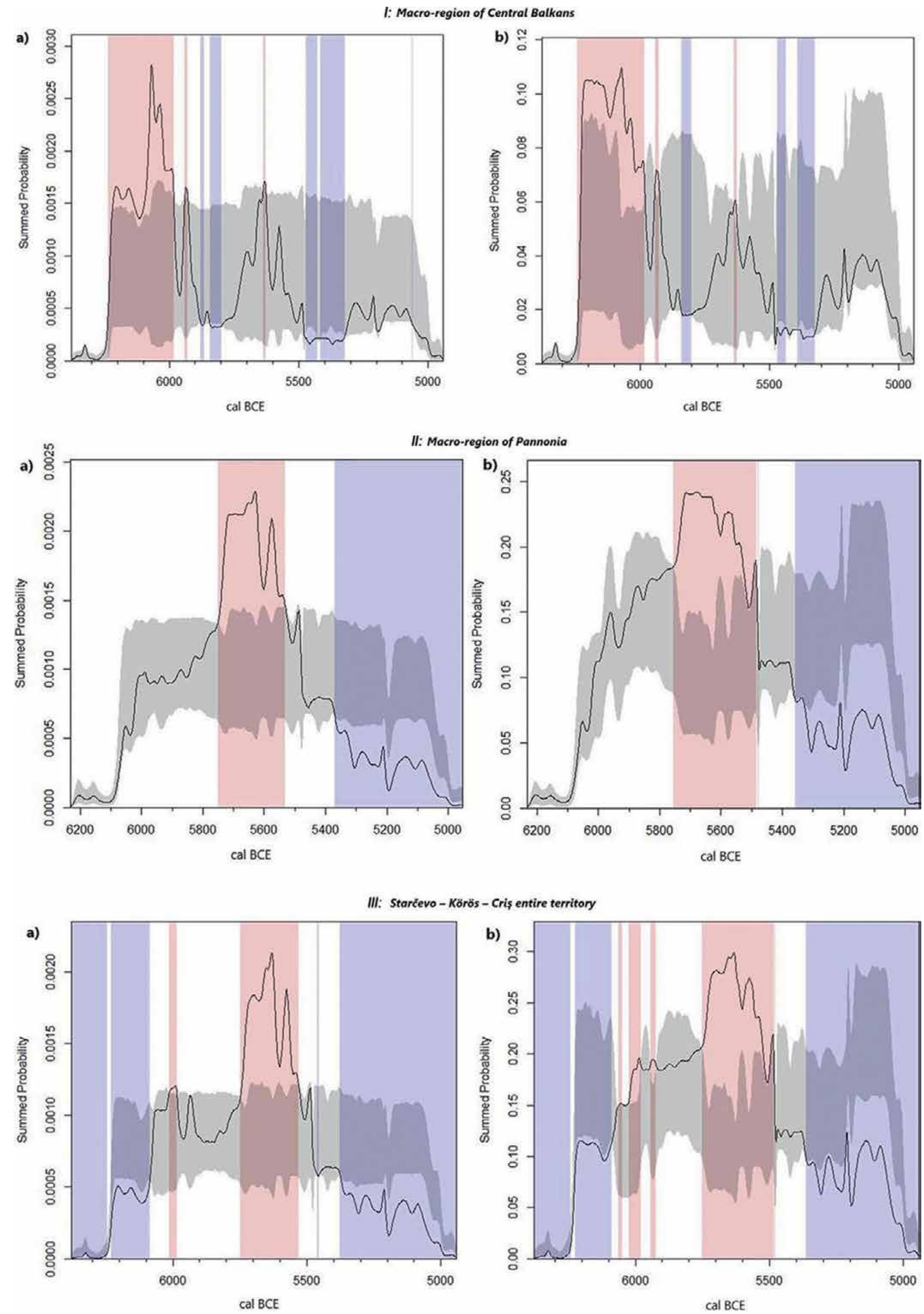

Figure 8. I. The results of the SCPD analysis on the sample from the macro-region of the central Balkans: a) with normalisation (p< 0.001); and b) without normalisation (p< 0.001) (N=148, number of bins=56). II. The results of the SCPD analysis on the sample from the macro-region of Pannonia: a) with normalisation (p< 0.001); and b) without normalisation (p< 0.001) (N=402, number of bins=154). III. The results of the SCPD analysis on the sample from the entire territory of the Starčevo – Körös – Criş complex: a) with normalisation (p< 0.001); and b) without normalisation (p< 0.001) (N=550, number of bins=210). For all three parts, the black line represents the empirical SCPD curve, obtained on the radiocarbon dates; the CI are represented with the grey area; and significant deviations are represented with colours – red for the significant increase and blue for the significant decrease on the curve. The figures were produced by T. Blagojević in the R programming language using the rcarbon package (Bevan and Crema 2018; Crema and Bevan 2020).

Macro-region of the central Balkans

The central Balkans sample consists of radiocarbon dates from the regions of southern and central Serbia. The results are statistically significant and resemble the well-known pattern from previous studies and individual regions, with two distinct peaks and a drop between them (Fig. 8.I) (Porčić *et al.* 2016; 2021; Blagojević 2022). However, in this case, the second drop is not as pronounced as in the results from previous studies. The reason could be the lack of dates from Vojvodina in this sample. These dates contributed more to the second peak, since they are younger than the ones from the southern and central Serbia regions.

Macro-region of Pannonia

In the macro-region of Pannonia, the SCPD curve starts to rise around 6100 cal BCE, but it is a gradual rise that becomes pronounced only around 5750 cal BCE, reaching a peak around 5650 cal BCE (Fig. 8.II). This episode of growth lasts for approximately another 100 years, after which the curve drops gradually. When the analysis was performed without normalisation, it produced a generally similar pattern, except that the episode of growth was less abrupt.

Starčevo – Körös – Criş entire territory

The pattern observed for the entire SKC complex shows the beginning of population growth as early as around 6250 cal BCE, but on this scale, it is a rather gradual growth (Fig. 8.III). The first peak occurred around 6000 cal BCE, followed by a statistically insignificant drop. More pronounced growth starts around 5800 cal BCE, with a peak around 5650 cal BCE. This episode lasts until around 5550 cal BCE, and it is followed by a drop. The drop is the most noticeable around 5200 cal BCE. As in the case of the macro-region of Pannonia, the difference between the results before and after the application of the normalisation procedure shows a similar pattern, with the episode of growth being less pronounced.

The results of the population dynamics reconstruction presented here vary in terms of patterns observed for individual regions (Table 1). These variations could be seen both within the shape of the curve and its fluctuations and in the chronology of different episodes of growth and decline in the population size. In terms of the overall chronology of the SKC cultural complex, these findings highlight the previously described differences in the neolithisation processes of different regions in this territory, as well as the different timings of the arrival of the Neolithic.

Population growth has been confirmed in almost all the regions included. The boom-and-bust pattern is the most pronounced in the territory of Serbia, while in the territory of the Great Hungarian Plain, there is no evidence of the population rebounding after the drop on the SCPD curve. Results on the macro-regional level resemble the assumed direction of the spread of the Neolithic, since the southern regions (in the central Balkans) show an abrupt increase of the SCPD curve much earlier than in Pannonia. All these changes are smoothed out on the curve for the entire SKK territory but correspond to the patterns observed in other European regions (Shennan *et al.* 2013; Timpson *et al.* 2014; Crema *et al.* 2016; Silva and Vander Linden 2017). At this level, the observed changes in population dynamics are more gradual, especially at the beginning of the Neolithic. Even though the curve shows minor fluctuations starting as early as ~6250 cal BCE, the real rise starts only around 6100 cal BCE, with the peak around 6000 cal BCE. This point represents the period of the most intensive population growth in some of the regions (the central Balkans and Romania – if the growth in Romania is to be interpreted

Territory	Cultural affiliation	Time span (years cal BCE)	N sites included in the SCPD analysis	N dates	N bins	Global p-value (with normalisation)	Global p-value (without normalisation)	Qualitative evidence for NDT	Presence of a significant point-to-point test
Region of Romania	Criş culture	5900-5100	15	58	30	0.016	0.005	Possibly	Not performed
Region of the Great Hungarian Plain	Körös culture	6000-5300	22	144	55	<0.001	<0.001	Yes	Not performed
Region of eastern and northern Croatia	Starčevo culture	6000-5300	11	41	20	0.06	0.02	Yes	Yes
Region of southern Serbia	Starčevo culture	6250-5300	8	40	17	0.123	0.143	Yes	Yes
Region of Central Serbia	Starčevo culture	6250-5300	19	108	39	0.015	0.002	Yes	I: Yes II: No
Region of Vojvodina	Starčevo culture	6000-5300	25	148	46	0.004	0.004	Yes	No
Macro-region of central Balkans	Starčevo culture	6250-5300	27	148	56	<0.001	<0.001	Yes	Not performed
Macro-region of Pannonia	Starčevo, Körös and Criş cultures	6000-5300	77	402	154	<0.001	<0.001	Yes	Not performed
Entire Starčevo – Körös – Criş complex	Starčevo, Körös and Criş cultures	6250-5100	104	550	210	<0.001	<0.001	Yes	Not performed

Table 1. Summary of the basic information for and results of the SCPD analyses for individual regions, macro-regions and the entire Starčevo – Körös – Criş cultural complex.

as an indicator of the demographic change), while in other regions (the Great Hungarian Plain, Croatia), it is the period of the beginning of population growth. Considering these results for individual regions, it could be argued that the period around 6000 cal BCE is the period of the most intensive settling in the territory of the SKC cultural complex. This might represent the signal of an influx of new populations in this territory due to Early Neolithic migrations and as proposed by the travelling wave-front model (Silva and Vander Linden 2017). The time span between ~5900 and ~5800 cal BCE is marked by a drop on the curve, which is not particularly pronounced but coincides with the abrupt drop on the population proxy curve for the central Balkans. This indicates a high effect of the central Balkans sample and could potentially indicate that large-scale demographic change occurred in this region. On the other hand, the pattern is in accordance with the boom-and-bust fluctuations and the assumptions of the NDT. The rise on the population curve that follows, with the peak around 5650 cal BCE, could represent a signal of the rise in fertility resulting from changes in the way of life after the period of consolidation in the area.

Conclusion

Over the past decade, the SCPD method has proven to be an important tool for observing and defining different patterns of demographic change that are an integral part of the neolithisation process (Shennan *et al.* 2013; Timpson *et al.* 2014; Crema *et al.* 2016; Porčić *et al.* 2016; Blagojević *et al.* 2017; Crema and Bevan 2020; Porčić *et al.* 2021; Blagojević 2022). Various criticisms have led to improvements in the method itself and in its application. What does not seem to be amenable to improvement is the ability to detect patterns of change with a very small sample. Although there is no official consensus on the lower limit of the sample size, research such as that presented here could help in its determination. At the same time, researchers should take into account whether they are working with a probabilistic sample (which is less often the case) or with a sample that

requires a binning procedure, which also leads to a reduction in the effective sample size, directly affecting the statistical significance of the obtained results. In the case of this research, the results were not statistically significant where the sample consisted of 40 dates and 20 bins, namely the region of eastern and northern Croatia (Fig. 4, Table 1), and where the sample consisted of 40 dates and 17 bins, namely the region of southern Serbia (Fig. 5, Table 1), and it can be assumed that the sample size played a key role in the results obtained. On the other hand, this does not necessarily mean that the accuracy of the observed patterns should be a priori rejected. It should, rather, be reassessed by including other indicators of changes in population dynamics. In this regard, it is important to emphasise once again that the SCPD results represent primarily an analytical tool that allows us to identify and track certain patterns but that to interpret those patterns, additional archaeological and anthropological indicators of demographic change must be used.

The results presented in this paper allowed for the identification of patterns in population dynamics in the territory that was crucial for the spread of the Neolithic way of life throughout Europe. They have shown that the beginning of the Neolithic was marked by a pronounced rise in population size, which probably indicates the arrival of a new population. The fluctuations that follow are regionally specific but consist of indicators of a decline in population size in most of the seven regions analysed. The results are in line with the predictions of the NDT and the hypothesis regarding the two phases of population growth and decline. The results allowed the identification not only of patterns of demographic change, but also of an important chronological component of the neolithisation processes, at both a regional and macro-regional level. In this way, our results provide baseline data that can be used in future research. Future research should focus on explaining the anthropological reality that underlies the observed patterns, by using different anthropological and archaeological data, such as settlement archaeology, specifically settlement size and distribution.

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References

Bailey, D.W., 2000. *Balkan prehistory: exclusion, incorporation and identity*. London: Routledge.

Bánffy, E., Juhász, I., Sümegi, P., 2007. A prelude to the Neolithic in the Balaton region - new results to an old problem. *In:* M. Spataro and P. Biagi, eds. *A Short Walk through the Balkans: The First Farmers of the Carpathian Basin and Adjacent Regions*. Quaderno 12. Trieste: Società Preistoria Protostoria Friuli-V.G., 223-237.

Bevan, A. and Crema, E.R., 2018. *rcarbon v1.1.3: methods for calibrating and analysing radiocarbon dates*. Available from: https://CRAN.R-project.org/package=rcarbon

Bevan, A., Colledge, S., Fuller, D., Fyfe, R., Shennan, S., Stevens, C., 2017. Holocene fluctuations in human population demonstrate repeated links to food production and climate. *Proceedings of the National Academy of Sciences*, 114 (49), E10524-E10531. DOI: 10.1073/pnas.1709190114

Biagi, P. and Spataro, M., 2005. New observations on the radiocarbon chronology of the Starčevo-Criş and Körös cultures. *In:* L. Nikolova and J. Higgins, eds. *Prehistoric archaeology and anthropological theory and education. Reports of Prehistoric Research Projects 6-7*. Sofia-Karlovo and Salt Lake City: Prehistory Foundation and International Institute of Anthropology, 35-40.

Binford, L.R. and Chasko, W.J., 1976. Nunamiut demographic history: a provocative case. *In:* E.B.W. Zubrow ed. *Demographic anthropology: quantitative approaches*. Albuquerque: University of New Mexico Press, 63-143.

Blagojević, T., 2022. *Demografija i obrasci naseljavanja neolitskih populacija na teritoriji Srbije između 6200. i 5300. god. p. n. e.* [Demography and settlement patterns of the Neolithic populations in the territory of Serbia between 6200 and 5300 cal BC]. Unpublished PhD dissertation. Faculty of Philosophy, University of Belgrade.

Blagojević, T., Porčić, M., Penezić, K., Stefanović, S., 2017. Early Neolithic population dynamics in eastern Balkans and the Great Hungarian Plain. *Documenta Praehistorica*, 44, 18-33. DOI: 10.4312/dp.44.2

Blažić, S., 2005. Appendix 2. The faunal assemblage. *In:* P. Biagi and S. Karmanski, eds. *Donja Branjevina: a Neolithic settlement near Deronje in the Vojvodina (Serbia)*. Trieste: Museo Civico di Storia Naturale, 74-77.

Bocquet-Appel, J.-P., 2002. Paleoanthropological traces of a Neolithic demographic transition. *Current Anthropology*, 43 (4), 637-650.

Bocquet-Appel, J.-P., 2008. Explaining the Neolithic demographic transition. *In:* J.-P. Bocquet-Appel and O. Bar-Yosef, eds. *The Neolithic demographic transition and its consequences*. Berlin: Springer, 35-55.

Bocquet-Appel, J.-P., 2011a. When the world's population took off: the springboard of the Neolithic demographic transition. *Science*, 333, 560-561. DOI: 10.1126/science.1208880

Bocquet-Appel, J.-P., 2011b. The Agricultural Demographic Transition during and after the agriculture inventions. *Current Anthropology*, 52 (S4), S497-S510.10.1086/659243. DOI: 10.1086/659243

Bocquet-Appel, J.-P., 2013. Demographic transitions. *In:* C. Smith, ed. *Encyclopedia of Global Archaeology*. New York: Springer, 1-8.

Bocquet-Appel, J.-P and Naji, S., 2006. Testing the hypothesis of a worldwide Neolithic demographic transition - corroboration from American cemeteries. *Current Anthropology*, 47 (2), 341-365.

Bocquet-Appel, J.-P and Bar-Yosef, O., eds., 2008. *The Neolithic demographic transition and its consequences*. Berlin: Springer.

Bocquet-Appel, J.-P., Naji, S., Bandy, M., 2008. Demographic and health changes during the transition to agriculture in North America. *In:* J.-P. Bocquet-Appel, ed. *Recent advances in palaeodemography: data, techniques, patterns*. Berlin: Springer, 277-292.

Bocquet-Appel, J.-P., Naji, S., Vander Linden, M., Kozłowski, J.K., 2009. Detection of diffusion and contact zones of early farming in Europe from the space-time distribution of 14C dates. *Journal of Archaeological Science*, 36 (3), 807-820. DOI: 10.1016/j.jas.2008.11.004

Bogdanović, M., 1988. Architecture and structural features at Divostin. *In:* A. McPherron and D. Srejović, eds. *Divostin and the Neolithic of central Serbia. Ethnology Monographs*. Pittsburgh: University of Pittsburgh, Department of Anthropology, 35-142.

Bonsall, C., Vasić, R., Boroneanţ, A., Roksandić, M., Soficaru, A., McSweeney, K., Evatt, A., Aguraiuja, Ü., Pickard, C., Dimitrijević, V., Higham, T., Hamilton, D., Cook, G.,

2015. New AMS 14C dates for human remains from stone age sites in the Iron Gates reach of the Danube, southeast Europe. *Radiocarbon*, 57 (1), 33-46. DOI:10.2458/azu_rc.57.18188

Borić, D., 2009. Absolute dating of metallurgical innovations in the Vinča culture of the Balkans. *In:* T. Kienlin T. and B. Roberts, eds. *Metals and societies: studies in honour of Barbara S. Ottaway*. Bonn: Dr. Rudolf Habelt GmbH, 191-245.

Borić, D., 2011. Adaptations and transformations of the Danube Gorges foragers (c. 13.000-5500 BC): an overview. *In:* R. Krauß, ed. *Beginnings – new research in appearance of the Neolithic between northwest Anatolia and the Carpathian Basin: papers of the international workshop 8th-9th April 2009, Istanbul*. Rahden: Verlag Marie Leidorf GmbH, 157-203.

Borić, D. and Price, T.D., 2013. Strontium isotopes document greater human mobility at the start of the Balkan Neolithic. *Proceedings of the National Academy of Sciences*, 110 (9), 3298-3303. DOI:10.1073/pnas.1211474110

Botić, K., 2016. Neolithisation of Sava-Drava-Danube interfluve at the end of the 6600-6000 BC period of rapid climate change: a new solution to an old problem. *Documenta Praehistorica*, 43, 183-207. DOI:10.4312/dp.43.9

Bökönyi, S., 1988. The Neolithic fauna of Divostin. *In:* A. McPherron and D. Srejović, eds. *Divostin and the Neolithic of central Serbia*. Pittsburgh: University of Pittsburgh, 419-445.

Brami, M. and Heyd, V., 2011. The origins of Europe's first farmers: the role of Hacilar and western Anadolia, fifty years on. *Praehistorische Zeitschrift*, 86, 165-206. DOI:10.1515/pz.2011.011

Buikstra, J.E., Konigsberg, L.W., Bullington, J., 1986. Fertility and the development of agriculture in the prehistoric Midwest. *American Antiquity*, 51, 528-546.

Clason, A.T., 1980. Padina and Starčevo: game, fish and cattle. *Palaeohistoria* 22, 141-173.

Cohen, M.N., 2008. Implications of the Neolithic demographic transition for worldwide health and mortality in prehistory. *In:* J.-P. Bocquet-Appel and O. Bar-Yosef, eds. *The Neolithic demographic transition and its consequences*. Berlin: Springer, 481-500.

Contreras, D.A. and Meadows, J., 2014. Summed radiocarbon calibrations as a population proxy: a critical evaluation using a realistic simulation approach. *Journal of Archaeological Science*, 52, 591-608.

Crema, E.R. and Bevan, A., 2020. Inference from large sets of radiocarbon dates: software and methods. *Radiocarbon*, 63 (1), 23-39. DOI:10.1017/RDC.2020.95

Crema, E.R., Habu, J., Kobayashi, K., Madella, M., 2016. Summed probability distribution of 14C dates suggests regional divergences in the population dynamics of the Jomon period in eastern Japan. *PLoS One*, 11 (4), p.e0154809. DOI:10.1371/journal.pone.0154809

Davison, K., Dolukhanov, P.M., Sarson, G.R., Shukurov, A., Zaitseva, G.I., 2007. A pan-European model of the Neolithic. *Documenta Praehistorica*, XXXIV, 139-154. DOI:10.4312/dp.34.10

de Becdelièvre, C., Goude, G., Jovanović, J., Herrscher, E., Le Roy, M., Routtier, S., Stefanović, S., 2015. Prehistoric motherhood: diet from pregnancy to baby-led weaning in the Danube Gorges Mesolithic-Neolithic. *American Journal of Physical Anthropology*, 156, 116-116.

de Becdelièvre, C., Blagojević, T., Jovanović, J., Stefanović, S., Hofmanová, Z., Porčić, M., 2021. Palaeodemography of the foraging to farming transition: insights from the Danube Gorges Mesolithic-Neolithic transformations. *In:* A. Degioanni, E. Herrscher, S. Naji, eds. *Journey of a committed paleodemographer: farewell to Jean-Pierre Bocquet-Appel*. Collection Préhistoire de la méditerranée. Aix-en-Provence: Presses Universitaires de Provence, 113-133.

Edinborough, K., Porčić, M., Martindale, A., Brown, T.J., Supernant, K., Ames, K.M., 2017. Radiocarbon test for demographic events in written and oral history. *Pro-*

ceedings of the National Academy of Sciences, 114 (47), 12436-12441. DOI: 10.1073/pnas.1713012114

Ehrich, R.W. and Bankoff, H.A., 1990. Absolute chronology of the Neolithic in southeastern Europe. *In:* R. Ehrich, ed. *Chronologies in Old World archaeology*. Chicago: University of Chicago Press, 375-394.

Fort, J., 2012. Synthesis between demic and cultural diffusion in the Neolithic transition in Europe. *Proceedings of the National Academy of Sciences*, 109 (46), 18669-18673. DOI: 10.1073/pnas.1200662109

Garašanin, M., 1979. *Centralnobalkanska zona. U: A. Benac, ur. Praistorija jugoslavenskih zemalja II, Neolitsko doba*. Sarajevo: Akademija nauka i umjetnosti Bosne i Hercegovine, Centar za balkanološka ispitivanja, 79-212.

Garašanin, M., 1982. *The Stone Age in the central Balkan area. Cambridge Ancient History, Volume 3, Part 1*. Cambridge: Cambridge University Press, 75-135.

Garašanin, M. and Radovanović, I., 2001. A pot in House 54 at Lepenski Vir I. *Antiquity*, 75, 118-125.

Gimbutas, M., 1974. Chronology of Obre I and Obre II. *Wissenschaftliche Mitteilungen des Bosnich-Herzegowinischen Landesmuseum*, IV, 15-35.

Greenfield, H. and Draşovean, F., 1994. An Early Neolithic Starčevo-Criş settlement in the Romanian Banat: preliminary report on the 1992 excavations at Foeni-Sălaș Annale Banatului. *Journal of the Museum of the Banat*, 3, 5-50.

Greenfield, H.J. and Jongsma, T., 2008. Sedentary pastoral gatherers in the Early Neolithic: architectural, botanical, and zoological evidence for mobile economies from Foeni-Sălaș, south-west Romania. *In:* D. Bailey, A.W.R. Whittle, D. Hofmann, eds. *Living well together? Settlement and materiality in the Neolithic of south-east and central Europe*. Oxford: Oxbow, 108-130.

Greenfield, H.J., Greenfield Jongsma, T., Jezik, S., 2014. Subsistence and settlement in the Early Neolithic of temperate SE Europe: a view from Blagotin, Serbia. *Archaeologia Bulgarica*, 18 (1), 1-33.

Gurova, M. and Bonsall, C 2014. 'Pre-Neolithic' in Southeast Europe: a Bulgarian perspective. *Documenta Praehistorica*, XLI, 95-109. DOI: 10.4312/dp.41.5

Haak, W., Balanovsky, O., Sanchez, J.J., Koshel, S., Zaporozhchenko V., Adler, C.J., Der Sarkissian, C.S., Brandt, G., Schwarz, C., Nicklisch, N. and Dresely, V., 2010. Ancient DNA from European Early Neolithic farmers reveals their Near Eastern affinities. *PLoS Biology*, 8 (11), e1000536. DOI: 10.1371/journal.pbio.1000536

Hofmanová, Z., Kreutzer, S., Hellenthal, G., Sell, C., Diekmann, Y., Díez-Del-Molino, D., van Dorp, L., López, S., Kousathanas, A., Link, V., Kirsanow, K., Cassidy, L.M., Martiniano, R., Strobel, M., Scheu, A., Kotsakis, K., Halstead, P., Triantaphyllou, S., Kyparissi-Apostolika, N., Urem-Kotsou, D., Ziota, C., Adaktylou, F., Gopalan, S., Bobo, D.M., Winkelbach, L., Blöcher, J., Unterländer, M., Leuenberger, C., Çilingiroğlu, Ç., Horejs, B., Gerritsen, F., Shennan, S.J., Bradley, D.G., Currat, M., Veeramah, K.R., Wegmann, D., Thomas, M.G., Papageorgopoulou, C., Burger, J., 2016. Early farmers from across Europe directly descended from Neolithic Aegeans. *Proceedings of the National Academy of Sciences*, 113 (25), 6886-6891. DOI: 10.1073/pnas.1523951113

Jovanović, J., 2017. *The diet and health status of the Early Neolithic communities of the central Balkans (6200-5200 BC)*. Unpublished PhD dissertation. Faculty of Philosophy, University of Belgrade.

Jovanović, J., Blagojević, T., Marković, J., Novak, M., Bedić, Ž., Naumov, G., Kanzurova, E.S., Los, D., Hutinec, M., Fidanoski, L., Skelac, G., Šlaus, M., Stefanović, S., 2021. New radiocarbon dates, stable isotope, and anthropological analysis of prehistoric human bones from the Balkans and southwestern Carpathian Basin. *Documenta Praehistorica*, 48, 2-29.

Kalicz, N., Virág, Zs., Biró T., K., 1998. The northern periphery of the Early Neolithic Starčevo culture in south-western Hungary: a case study of an excavation at Lake Balaton. *Documenta Praehistorica*, 25: 151-187.

Kosse, K., 1979. *Settlement ecology of the Early and Middle Neolithic Körös and Linear Pottery cultures in Hungary*. BAR International Series 64. Oxford: BAR.

Lesure, R.G., 2008. The Neolithic demographic transition in Mesoamerica? Larger implications of the strategy of relative chronology. *In:* J.-P. Bocquet-Appel and O. Bar-Yosef, eds. *The Neolithic demographic transition and its consequences*. Springer: Berlin, 107-138.

Lesure, R.G., Martin, L.S., Bishop, K.J., Jackson, B., Chykerda, C.M., 2014. The Neolithic demographic transition in Mesoamerica. *Current Anthropology*, 55(5), 654-664.

Luca, S.A., Suciu, C.I., Dumitrescu-Chioar, F., 2011. Starčevo-Criş culture in western part of Romania – Transylvania, Banat, Crişana, Maramureş, Oltenia and western Muntenia: Repository, Distribution Map, State of Research and Chronology. *In:* S.A. Luca and C.I. Suciu, eds. *The first Neolithic sites in central/South-East European Transect, Volume II, Early Neolithic (Starčevo-Criş) Sites on the Territory of Romania*. BAR International Series 2188. Oxford: BAR, 7-17.

Марковић, Н., Булатовић, Ј., Јовановић, Ј. и Катић, Б., 2018 Биоархеолошка перспектива ранонеолитског налазишта Баташево [Bioarchaeological perspective on the Early Neolithic site of Bataševo]. У: И. Тодоровић, Г. Јашовић, И. Бецић и Љ. Васиљевић, ур. Јухорски запис. Крушевац, Историјски архив Крушевац, 29-38.

Mathieson, I., Lazaridis, I., Rohland, N., Mallick, S., Patterson, N., Roodenberg, S.A., Harney, E., Stewardson, K., Fernandes, D., Novak, M., Sirak, K., Gamba, C., Jones, E.R., Llamas, B., Dryomov, S., Pickrell, J., Arsuaga, J.L., de Castro, J.M., Carbonell, E., Gerritsen, F., Khokhlov, A., Kuznetsov, P., Lozano, M., Meller, H., Mochalov, O., Moiseyev, V., Guerra, M.A., Roodenberg, J., Vergès, J.M., Krause, J., Cooper, A., Alt, K.W., Brown, D., Anthony, D., Lalueza-Fox, C., Haak, W., Pinhasi, R., Reich, D., 2015. Genome-wide patterns of selection in 230 ancient Eurasians. *Nature*, 528, 499-523. DOI:10.1038/nature16152

Mathieson, I., Alpaslan-Roodenberg, S., Posth, C., Szécsényi-Nagy, A., Rohland, N., Mallick, S., Olalde, I., Broomandkhoshbacht, N., Candilio, F., Cheronet, O., Fernandes, D., 2018. The genomic history of southeastern Europe. *Nature*, 555 (7695) 197-203. DOI:10.1038/nature25778

Mester, Zs. and Rácz, B., 2010. The spread of the Körös culture and the raw material sources in the northeastern part of the Carpathian Basin: a research project. *In:* J. K. Kozłowski and P. Raczky, eds. *Neolithization of the Carpathian Basin: northernmost Distribution of the Starčevo/Körös culture*, Kraków: Polska Akademia Umiejętności, 23-35.

Oross, K. and Siklósi, Zs., 2012. Relative and absolute chronology of the Early Neolithic in the Great Hungarian Plain. *In:* A. Anders and Zs. Siklósi, eds. *The first Neolithic sites in central/South-East European Transect, Volume III, The Körös culture in eastern Hungary*. BAR International Series 2334. Oxford: BAR, 129-159.

Özdoğan, M., 2014. A new look at the introduction of the Neolithic way of life in southeastern Europe: changing paradigms of the expansion of the Neolithic way of life. *Documenta Praehistorica*, XLI, 33-49. DOI:10.4312/dp.41.2

Paluch, T., 2012. Characteristics of the Körös culture in the southern section of the Great Hungarian Plain. *In:* A. Anders and Zs. Siklósi, eds. *The first Neolithic sites in central/South-East European Transect, Volume III, The Körös culture in eastern Hungary*. BAR International Series 2334. Oxford: BAR, 49-52.

Papathanasiou, A., 2011. Health, Diet and Social Implications in Neolithic Greece from the study of Human Osteological material. *In:* R. Pinhasi and J.T. Stock, eds. *Human Bioarchaeology of the Transition to Agriculture*. Chichester: Wiley-Blackwell, 87-106.

Perlès, C., Quiles, A., Valladas, H., 2013. Early seventh-millennium AMS dates from domestic seeds in the Initial Neolithic at Franchthi Cave (Argolid, Greece). *Antiquity*, 87 (338), 1001-1015. DOI:10.1017/S0003598X00049826

Pinhasi, R., Fort, J., Ammerman, A.J., 2005. Tracing the origin and spread of agriculture in Europe. *PLoS Biology*, 3 (12), e2220-8. DOI:10.1371/journal.pbio.0030410

Pinhasi, R., Thomas, M.G., Hofreiter, M., Currat, M., Burger, J., 2012. The genetic history of Europeans. *Trends in Genetics*, 28 (10), 496-505. DOI:10.1016/j.tig.2012.06.006

Porčić, M. and Nikolić, M., 2016. The Approximate Bayesian Computation approach to reconstructing population dynamics and size from settlement data: demography of the Mesolithic-Neolithic transition at Lepenski Vir. *Archaeological and Anthropological Sciences*, 8 (1), 169-86. DOI:10.1007/s12520-014-0223-2

Porčić, M., Blagojević, T., Stefanović, S., 2016. Demography of the Early Neolithic population in central Balkans: population dynamics reconstruction using summed radiocarbon probability distributions. *PLoS One*, 11 (8), e0160832.

Porčić, M., Blagojević, T., Pendić, J., Stefanović, S., 2020. The timing and tempo of the Neolithic expansion across the central Balkans in the light of the new radiocarbon evidence. *Journal of Archaeological Science: Reports*, 33, 102528. DOI:10.1016/j.jasrep.2020.102528

Porčić, M., Blagojević, T., Pendić, J., Stefanović, S., 2021. The Neolithic demographic transition in the central Balkans: population dynamics reconstruction based on new radiocarbon evidence. *Philosophical Transactions of the Royal Society B*, 376 (1816) 20190712. DOI:10.1098/rstb.2019.0712

Price, T.D., 2000. Europe's first farmers: an introduction. *In:* T.D. Price, ed. *Europe's first farmers*. Cambridge: Cambridge University Press, 1-18.

R Core Team 2019. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Wien, Austria. Available from: http://www.R-project.org/

Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hajdas, I., Heaton, T., Hogg, A., Hughen, K., Kromer, B., Manning, S., Muscheler, R., Palmer, J., Pearson, C., van der Plicht, J., Reimer, R., Richards, D., Scott, E, Southon, J., Turney, C., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., Talamo, S., 2020. The IntCal20 northern hemisphere radiocarbon age calibration curve (0-55 cal kBP). *Radiocarbon*, 62 (4), 725-757. DOI:10.1017/RDC.2020.41

Ryder, N.B., 1975. Notes on stationary populations. *Population Index*, 41 (1), 3-28.

Shennan, S., Downey, S.S., Timpson, A., Edinborough, K., Colledge, S., Kerig, T., Manning, K., Thomas, M.G., 2013. Regional population collapse followed initial agriculture booms in mid-Holocene Europe. *Nature Communications*, 4 (1), 1-8. DOI:10.1038/ncomms3486

Silva, F. and Vander Linden, M., 2017. Amplitude of travelling front as inferred from 14 C predicts levels of genetic admixture among European early farmers. *Scientific Reports*, 7 (1), 1-9. DOI:10.1038/s41598-017-12318-2

Szécsényi-Nagy, A., Brandt, G., Haak, W., Keerl, V., Jakucs, J., Möller-Rieker, S., Köhler, K., Mende, B.G., Oross, K., Marton, T., Osztás, A., 2015. Tracing the genetic origin of Europe's first farmers reveals insights into their social organization. *Proceedings of the Royal Society B*, 282 (1805) 20150339. DOI:10.1098/rspb.2015.0339

Timpson, A., Colledge, S., Crema, E., Edinborough, K., Kerig, T., Manning, K., Thomas, M.G., Shennan, S., 2014. Reconstructing regional population fluctuations in the European Neolithic using radiocarbon dates: a new case-study using an improved method. *Journal of Archaeological Science*, 52, 549-557. DOI:10.1016/j.jas.2014.08.011

Tasić, N.N., 2007. Neolit u senci – još jedan osvrt na starčevačka naselja u Bosni. *Godišnjak centra za balkanološka ispitivanja*, 34, 5-16.

Valeggia, C. and Ellison, P.T., 2004. Lactational amenorrhoea in well-nourished Toba women of Formosa, Argentina. *Journal of Biosocial Science*, 36 (5), 573-595. DOI:10.1017/S0021932003006382
Vander Linden, M., Pandžić, I., Orton, D., 2014. New radiocarbon dates for the Neolithic period in Bosnia and Herzegovina. *Godišnjak Centar za Balkanološka Ispitivanja, Akademija Nauka i Umjetnosti Bosne i Hercegovine*, 43, 7-34. DOI:10.5644/Godisnjak.CBI.ANUBiH-43.35
Weninger, B., Clare, L., Jöris, O., Jung, R., Edinborough, K., 2015. Quantum theory of radiocarbon calibration. *World Archaeology*, 47 (4), 543-566. DOI:10.1080/00438243.2015.1064022
Whittle, A.W.R., Bartosiewicz, L., Borić, D., Pettitt, P., Richards, M., 2002. In the beginning: new radiocarbon dates for the Early Neolithic in northern Serbia and south-east Hungary. *Antaeus*, 25, 63-117.
Williams, A.N., 2012. The use of summed radiocarbon probability distributions in archaeology: a review of methods. *Journal of Archaeological Science*, 39 (3), 578-589.
Wittwer-Backofen, U. and Tomo, N., 2008. From health to civilization stress? In search for traces of a health transition during the Early Neolithic in Europe. *In:* J.P. Bocquet-Appel and O. Bar-Yosef, eds. *The Neolithic demographic transition and its consequences*. Berlin: Springer, 501-538.

Appendix

Table with sites and radiocarbon dates included in this study. This data is also available on Zenodo.org (Blagojević et al. 2025).

Site name	LAT	LON	Region	Lab No	Uncal BP	Standard error	References
Alsónyék	46.203	18.735	Great Hungarian Plain	OxA-X-2583-19	6906	34	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-51452	6903	35	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-51449	6886	31	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11935	6857	31	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11940	6853	38	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11927	6852	31	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-51458	6850	33	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-57541	6830	35	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	OxA-30481	6822	36	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11934	6800	35	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	Poz-67494	6750	40	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	OxA-30353	6738	33	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-51454	6713	33	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11937	6709	34	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-51453	6708	33	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11933	6704	34	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11936	6698	34	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11939	6695	40	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	OxA-30354	6679	34	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11930	6672	35	Oross *et al.* 2016

Site name	LAT	LON	Region	Lab No	Uncal BP	Standard error	References
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11928	6677	27	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11932	6661	25	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-57540	6660	34	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11931	6657	30	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-51451	6656	32	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11926	6649	29	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	OxA-30231	6647	37	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-57542	6644	36	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	OxA-30230	6639	35	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	OxA-X-2586-27	6625	40	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11938	6617	38	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	SUERC-51450	6590	32	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	MAMS-11929	6571	34	Oross *et al.* 2016
Alsónyék	46.203	18.735	Great Hungarian Plain	Poz-67492	6480	40	Oross *et al.* 2016
Anište-Bresnica	43.871	20.588	Central Serbia	BRAMS-2331	7306	28	Porčić *et al.* 2021
Anište-Bresnica	43.871	20.588	Central Serbia	BRAMS-2333	7269	27	Porčić *et al.* 2021
Anište-Bresnica	43.871	20.588	Central Serbia	BRAMS-2330	7258	27	Porčić *et al.* 2021
Anište-Bresnica	43.871	20.588	Central Serbia	BRAMS-2332	7219	27	Porčić *et al.* 2021
Arnautovići	44.007	18.172	Eastern, northern and central Bosnia and Herzegovina	OxA-23339	6270	31	Vander Linden *et al.* 2014
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2390	6745	27	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2382	6730	27	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2388	6728	28	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2381	6725	27	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2383	6677	27	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2384	6655	28	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2386	6646	27	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2389	6632	27	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2387	6627	28	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2385	6605	28	Porčić *et al.* 2021
Autoput E-70, 521 km, lokalitet 1	44.980	19.732	Vojvodina	BRAMS-2424	6601	28	Porčić *et al.* 2021
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2374	6724	27	Porčić *et al.* 2021
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2375	6702	28	Porčić *et al.* 2021
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2371	6629	27	Porčić *et al.* 2021
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2379	6627	27	Porčić *et al.* 2021
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2377	6612	27	Porčić *et al.* 2021

Site name	LAT	LON	Region	Lab No	Uncal BP	Standard error	References
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2373	6609	27	Porčić *et al.* 2021
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2376	6589	28	Porčić *et al.* 2021
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2372	6587	27	Porčić *et al.* 2021
Autoput E-70, P2 sever (3)	44.999	19.666	Vojvodina	BRAMS-2378	6583	27	Porčić *et al.* 2021
Baciu – point Gura Baciului	46.775	23.503	Romania	GrA-24137	7140	45	Luca and Suciu (eds.) 2011
Baciu – point Gura Baciului	46.775	23.503	Romania	Lv-2157	6400	90	Luca and Suciu (eds.) 2011
Bakovača-Ostra	43.972	20.466	Central Serbia	BRAMS-2328	7285	27	Porčić *et al.* 2021
Bakovača-Ostra	43.972	20.466	Central Serbia	BRAMS-2329	7299	27	Porčić *et al.* 2021
Bakovača-Ostra	43.972	20.466	Central Serbia	BRAMS-2326	7248	27	Porčić *et al.* 2021
Bakovača-Ostra	43.972	20.466	Central Serbia	BRAMS-2327	7189	28	Porčić *et al.* 2021
Banja-Aranđelovac	44.307	20.567	Central Serbia	Bln-873	7048	100	Tasić 1997
Baštine-Obrež	44.728	19.979	Vojvodina	BRAMS-2409	6631	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2231	7277	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2230	7284	28	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2232	7309	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2227	7331	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2229	7265	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2236	7220	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2235	7136	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2233	7067	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2228	7063	27	Porčić *et al.* 2021
Batačevo	44.422	20.704	Central Serbia	BRAMS-2234	7057	27	Porčić *et al.* 2021
Beli Manastir – Popova zemlja	45.760	18.570	Eastern and northern Croatia	BRAMS-2817	6935	27	Jovanović *et al.* 2021
Beli Manastir – Popova zemlja	45.760	18.570	Eastern and northern Croatia	Poz-90129	6850	40	Mathieson *et al.* 2018
Biserna obala – Nosa	46.100	19.752	Vojvodina	OxA-8540	6740	75	Whittle *et al.* 2002
Blagotin	43.721	21.096	Central Serbia	OxA-8609	7270	50	Whittle *et al.* 2002
Blagotin	43.721	21.096	Central Serbia	OxA-8760	7230	50	Whittle *et al.* 2002
Blagotin	43.721	21.096	Central Serbia	BRAMS-2404	7104	28	Porčić *et al.* 2021
Blagotin	43.721	21.096	Central Serbia	BRAMS-2405	7091	28	Porčić *et al.* 2021
Blagotin	43.721	21.096	Central Serbia	BRAMS-2403	7062	28	Porčić *et al.* 2021
Cârcea-Viaduct	44.265	23.889	Romania	Bln-1981	6540	60	Mantu 2000.
Cârcea-Viaduct	44.265	23.889	Romania	Bln-1982	6430	60	Mantu 2000.
Cârcea-Viaduct	44.265	23.889	Romania	Bln-1983	6395	60	Mantu 2000.
Crnokalačka bara	46.100	19.752	Southern Serbia	BRAMS-2455	6194	27	Porčić *et al.* 2021
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2290	7293	29	Porčić *et al.* 2021
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2292	7275	29	Porčić *et al.* 2021
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2289	7244	29	Porčić *et al.* 2021
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2287	7236	29	Porčić *et al.* 2021
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2291	7235	29	Porčić *et al.* 2021
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2295	7228	29	Porčić *et al.* 2021

Site name	LAT	LON	Region	Lab No	Uncal BP	Standard error	References
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2293	7218	29	Porčić *et al.* 2021
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2288	7204	29	Porčić *et al.* 2021
Crnoklište	43.233	22.465	Southern Serbia	BRAMS-2294	7202	29	Porčić *et al.* 2021
Cuina Turcului	44.492	22.184	Romania	OxA-19205	7099	79	Bonsall *et al.* 2015
Cuina Turcului	44.492	22.184	Romania	OxA-19204	6973	60	Bonsall *et al.* 2015
Deszk-Olajkút	46.229	20.243	Great Hungarian Plain	OxA-9396	7030	50	Whittle *et al.* 2002
Deszk-Olajkút	46.229	20.243	Great Hungarian Plain	Bln-581	6605	100	Quitta and Kohl 1969
Deszk-Olajkút	46.229	20.243	Great Hungarian Plain	Bln-584	6540	100	Quitta and Kohl 1969
Deszk-Olajkút	46.229	20.243	Great Hungarian Plain	Bln-583	6410	100	Quitta and Kohl 1969
Deszk-Olajkút	46.229	20.243	Great Hungarian Plain	Bln-582a	6390	100	Quitta and Kohl 1969
Deszk-Olajkút	46.229	20.243	Great Hungarian Plain	Bln-582	6260	100	Quitta and Kohl 1969
Deszk-Olajkút	46.229	20.243	Great Hungarian Plain	OxA-9376	6225	55	Whittle *et al.* 2002
Dévaványa-Katalszeg	47.016	20.960	Great Hungarian Plain	Bln-86	6370	100	Kohl and Quitta 1963
Dévaványa-Réhelyi gát	47.069	20.919	Great Hungarian Plain	Bln-1379	6640	60	Anders and Siklósi 2012
Divostin	44.024	20.833	Central Serbia	Bln-899	7200	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	Bln-866a	7200	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	BRAMS-2402	7160	28	Porčić *et al.* 2021
Divostin	44.024	20.833	Central Serbia	Bln-866	7060	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	Bln-931	7050	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	Bln-826	7020	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	Bln-862	6995	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	Bln-824	6970	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	Bln-896	6945	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	BM-573	6935	100	McPherron *et al.* 1988
Divostin	44.024	20.833	Central Serbia	Bln-827	6910	100	McPherron *et al.* 1988
Donja Branjevina	45.452	19.217	Vojvodina	BRAMS-2449	6959	27	Stefanović *et al.* 2019
Donja Branjevina	45.452	19.217	Vojvodina	BRAMS-2450	6979	28	Stefanović *et al.* 2019
Donja Branjevina	45.452	19.217	Vojvodina	BRAMS-2451	6863	27	Stefanović *et al.* 2019
Donja Branjevina	45.452	19.217	Vojvodina	BRAMS-2452	6905	28	Stefanović *et al.* 2019
Donja Branjevina	45.452	19.217	Vojvodina	BRAMS-2453	6854	27	Stefanović *et al.* 2019

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Donja Branjevina	45.452	19.217	Vojvodina	BRAMS-2454	6837	27	Stefanović *et al.* 2019
Donja Branjevina	45.452	19.217	Vojvodina	GrN-15974	7155	50	Tasić 1993
Donja Branjevina	45.452	19.217	Vojvodina	GrN-15975	6955	50	Tasić 1993
Donja Branjevina	45.452	19.217	Vojvodina	GrN-15976	7140	90	Tasić 1993
Donja Branjevina	45.452	19.217	Vojvodina	GrN-24609	6810	80	Whittle *et al.* 2002
Donja Branjevina	45.452	19.217	Vojvodina	OxA-8555	6845	55	Whittle *et al.* 2002
Donja Branjevina	45.452	19.217	Vojvodina	OxA-8556	6775	60	Whittle *et al.* 2002
Donja Branjevina	45.452	19.217	Vojvodina	OxA-8557	7080	55	Whittle *et al.* 2002
Donji Miholjac-Vrancari	45.733	18.150	Eastern and northern Croatia	DeA-11080	6420	32	Botić 2017
Donji Miholjac-Vrancari	45.733	18.150	Eastern and northern Croatia	DeA-11168	6416	40	Botić 2018
Donji Miholjac-Vrancari	45.733	18.150	Eastern and northern Croatia	DeA-11166	6379	36	Botić 2018
Donji Miholjac-Vrancari	45.733	18.150	Eastern and northern Croatia	DeA-11167	6375	36	Botić 2018
Drenovac	43.782	21.439	Central Serbia	BRAMS-2244	7309	28	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2245	7133	27	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2246	7122	28	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2239	6739	27	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2242	6354	27	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2241	6302	27	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2237	6243	27	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2243	6226	27	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2238	6120	27	Porčić *et al.* 2021
Drenovac	43.782	21.439	Central Serbia	BRAMS-2240	6110	27	Porčić *et al.* 2021
Dudeştii Vechi-point Movila lui Deciov	46.05343	20.469	Romania	GrA-24115	6920	80	Luca and Suciu (eds.) 2011
Dudeştii Vechi-point Movila lui Deciov	46.05343	20.469	Romania	GrA-26951	6845	40	Luca and Suciu (eds.) 2011
Dudeştii Vechi-point Movila lui Deciov	46.05343	20.469	Romania	GrN-28111	6990	50	Luca and Suciu (eds.) 2011
Dudeştii Vechi-point Movila lui Deciov	46.05343	20.469	Romania	GrN-28113	6930	50	Luca and Suciu (eds.) 2011
Dudeştii Vechi-point Movila lui Deciov	46.05343	20.469	Romania	GrN-28876	6815	70	Luca and Suciu (eds.) 2011
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-10148	6665	50	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-10500	6900	60	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-10501	6885	50	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-10505	6845	50	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11845	6865	40	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11849	6660	40	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11850	6780	50	Bronk Ramsey *et al.* 2007

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Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11863	6825	45	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11868	6750	45	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11871	6930	40	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11982	6806	39	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11983	6915	36	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-11984	6893	36	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-12140	6729	32	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-12654	6889	36	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-12655	6830	35	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-12854	6774	45	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-12855	6596	42	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-12858	6782	42	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-12859	6818	44	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-12860	6826	41	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-13510	6731	43	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-13511	6785	45	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9325	6690	50	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9327	6870	50	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9328	6815	50	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9329	6950	45	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9330	6795	50	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9331	6815	45	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9332	6810	45	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9333	6860	45	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9334	6855	50	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9335	6920	50	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-9526	6915	50	Whittle *et al.* 2002
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-X-2040-07	6787	37	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-X-2040-08	6775	37	Bronk Ramsey *et al.* 2007
Ecsegfalva 23	47.13432	20.909	Great Hungarian Plain	OxA-X-2040-09	6780	39	Bronk Ramsey *et al.* 2007
Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9587	6915	45	Whittle *et al.* 2002
Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9583	6895	45	Whittle *et al.* 2002

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Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9588	6855	45	Whittle *et al.* 2002
Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9586	6850	45	Whittle *et al.* 2002
Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9582	6825	45	Whittle *et al.* 2002
Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9584	6825	45	Whittle *et al.* 2002
Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9590	6815	50	Whittle *et al.* 2002
Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9585	6795	50	Whittle *et al.* 2002
Endrőd 119	46.93401	20.632	Great Hungarian Plain	OxA-9589	6720	45	Whittle *et al.* 2002
Endrőd 35	46.9023	20.771	Great Hungarian Plain	Bln-1940	6615	60	Anders and Siklósi 2012
Endrőd 35	46.9023	20.771	Great Hungarian Plain	Bln-1960	6415	60	Anders and Siklósi 2012
Endrőd 39	46.98306	20.759	Great Hungarian Plain	Bln-1941	6785	55	Anders and Siklósi 2012
Endrőd-Varnyai tanya	46.91509	20.777	Great Hungarian Plain	OxA-9395	6595	50	Whittle *et al.* 2002
Foeni-Gaz	45.49103	20.87	Romania	GrA-25621	6925	45	Luca and Suciu (eds.) 2011
Foeni-Sălaş	45.52906	20.875	Romania	GrN-28454	7080	50	Luca and Suciu (eds.) 2011
Golokut-Vizić	45.178	19.47	Vojvodina	BRAMS-2400	6625	27	Porčić *et al.* 2021
Golokut-Vizić	45.178	19.47	Vojvodina	BRAMS-2401	6572	27	Porčić *et al.* 2021
Golokut-Vizić	45.178	19.47	Vojvodina	OxA-10147_duplicate	6590	50	Whittle *et al.* 2002
Golokut-Vizić	45.178	19.47	Vojvodina	OxA-8505	6550	55	Whittle *et al.* 2002
Golokut-Vizić	45.178	19.47	Vojvodina	OxA-8616	6560	50	Whittle *et al.* 2002
Golokut-Vizić	45.178	19.47	Vojvodina	OxA-8694	6525	50	Whittle *et al.* 2002
Golokut-Vizić	45.178	19.47	Vojvodina	OxA-8695	6520	50	Whittle *et al.* 2002
Gornja_Tuzla	44.45	18.76	Eastern, northern and central Bosnia and Herzegovina	GrN-2059	6640	75	Pinhasi *et al.* 2005
Gospođinci-Futog-Klisa I	45.243	19.722	Vojvodina	BRAMS-2391	6988	27	Porčić *et al.* 2021
Gospođinci-Futog-Klisa I	45.243	19.722	Vojvodina	BRAMS-2392	7001	28	Porčić *et al.* 2021
Gospođinci-Futog-Klisa I	45.243	19.722	Vojvodina	BRAMS-2393	7005	27	Porčić *et al.* 2021
Gospođinci-Futog-Klisa I	45.243	19.722	Vojvodina	BRAMS-2427	6982	28	Porčić *et al.* 2021
Gospođinci-Futog-Klisa I	45.243	19.722	Vojvodina	BRAMS-2428	7019	28	Porčić *et al.* 2021
Gospođinci-Futog-Klisa I	45.243	19.722	Vojvodina	BRAMS-2429	7051	28	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2360	7104	27	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2361	7006	27	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2362	7078	27	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2363	7066	28	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2364	7147	28	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2365	7118	28	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2366	7056	28	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2367	7169	28	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2369	7143	28	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2370	7134	28	Porčić *et al.* 2021
Gospođinci-Nove zemlje	45.404	20.003	Vojvodina	BRAMS-2594	7158	27	Porčić *et al.* 2021

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Grabovac-Đurića vinogradi	44.617	20.1	Central Serbia	BRAMS-2255	6848	27	Porčić *et al.* 2021
Grabovac-Đurića vinogradi	44.617	20.1	Central Serbia	BRAMS-2259	6844	27	Porčić *et al.* 2021
Grabovac-Đurića vinogradi	44.617	20.1	Central Serbia	BRAMS-2258	6812	27	Porčić *et al.* 2021
Grabovac-Đurića vinogradi	44.617	20.1	Central Serbia	BRAMS-2256	6809	27	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	Bln-869	7250	100	Bogdanović 1994
Grivac	44.004	20.698	Central Serbia	BRAMS-2414	7169	28	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2212	7100	27	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2215	7059	28	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2214	7042	27	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2209	7021	27	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2208	7014	27	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2210	7002	27	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2216	6986	27	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2211	6966	27	Porčić *et al.* 2021
Grivac	44.004	20.698	Central Serbia	BRAMS-2207	6931	27	Porčić *et al.* 2021
Grumăzeşti-Deleni	47.15528	26.412	Romania	RoAMS-729.7	6474	47	Diana *et al.* 2019
Grumăzeşti – Deleni	47.15528	26.412	Romania	RoAMS-729.5	6561	41	Diana *et al.* 2019
Grumăzeşti – Deleni	47.15528	26.412	Romania	RoAMS-729.6	6756	40	Diana *et al.* 2019
Gyálarét-Szilágyi major	46.24229	20.147	Great Hungarian Plain	Bln-75	7090	100	Kohl and Quitta 1963
Hódmezővásárhely-Kotacpart-Vata tanya	46.39366	20.245	Great Hungarian Plain	Bln-115	6450	100	Kohl and Quitta 1963
Ibrány-Nagyerdő	48.13426	21.714	Great Hungarian Plain	Poz-28216	6630	40	Domboroczki and Raczky 2010
Ibrány-Nagyerdő	48.13426	21.714	Great Hungarian Plain	Poz-28214	6570	40	Domboroczki and Raczky 2010
Iđoš	45.854	20.39	Vojvodina	BRAMS-2340	6181	26	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2341	6188	26	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2342	6167	27	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2343	6191	27	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2344	6186	26	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2345	6178	26	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2346	6212	27	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2347	6178	27	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2348	6200	27	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2349	6189	27	Porčić *et al.* 2021
Iđoš	45.854	20.39	Vojvodina	BRAMS-2415	6158	27	Porčić *et al.* 2021
Jaričište 1	44.466	20.231	Central Serbia	BRAMS-2272	6636	27	Porčić *et al.* 2021
Jaričište 1	44.466	20.231	Central Serbia	BRAMS-2273	6659	27	Porčić *et al.* 2021
Jaričište 1	44.466	20.231	Central Serbia	BRAMS-2277	6635	27	Porčić *et al.* 2021
Jaričište 1	44.466	20.231	Central Serbia	BRAMS-2278	7101	27	Porčić *et al.* 2021
Jaričište 1	44.466	20.231	Central Serbia	BRAMS-2437	6637	27	Porčić *et al.* 2021

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Jaričište 1	44.466	20.231	Central Serbia	NOSAMS_OS-78624	6660	35	Marić 2013
Jaričište 1	44.466	20.231	Central Serbia	OxA-22284	6729	36	Stefanović and Porčić 2015
Jaričište 1	44.466	20.231	Central Serbia	OxA-22285	6599	35	Stefanović and Porčić 2015
Kremenilo-Višesava	43.974	19.585	Central Serbia	BRAMS-2281	7105	27	Porčić *et al.* 2021
Kremenilo-Višesava	43.974	19.585	Central Serbia	BRAMS-2279	6683	27	Porčić *et al.* 2021
Kremenilo-Višesava	43.974	19.585	Central Serbia	BRAMS-2280	6652	27	Porčić *et al.* 2021
Kudoš-Šašinci	44.966	19.743	Vojvodina	OxA-8558	6770	60	Whittle *et al.* 2002
Lazarev grad-Crkvena građevina	43.583	21.317	Southern Serbia	BRAMS-2225	7225	28	Porčić *et al.* 2021
Limba Bordane – commu-nal Ciugud	46.03671	23.584	Romania	GrN-29052	6620	60	Cavruc *et al.* 1998
Limba Bordane – commu-nal Ciugud	46.03671	23.584	Romania	GrN-28457	6580	60	Cavruc *et al.* 1998
Ludoš-Budžak	46.099	19.811	Vojvodina	OxA-8554	6875	55	Whittle *et al.* 2002
Ludoš-Budžak	46.099	19.811	Vojvodina	OxA-8552	6725	60	Whittle *et al.* 2002
Ludoš-Budžak	46.099	19.811	Vojvodina	OxA-8553	6705	55	Whittle *et al.* 2002
Magareći mlin	45.64	19.013	Vojvodina	Grn-15973	7130	60	Whittle *et al.* 2002
Magareći mlin	45.64	19.013	Vojvodina	BRAMS-2397	7020	28	Porčić *et al.* 2021
Magareći mlin	45.64	19.013	Vojvodina	Grn-15972	7015	90	Tasić 1993
Magareći mlin	45.64	19.013	Vojvodina	BRAMS-2815	6965	27	Porčić *et al.* 2021
Magareći mlin	45.64	19.013	Vojvodina	BRAMS-2394	6933	28	Porčić *et al.* 2021
Magareći mlin	45.64	19.013	Vojvodina	Grn-15971	6910	45	Tasić 1993
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16630	6463	40	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16632	6260	35	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16633	6497	35	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16634	6454	39	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16635	6354	37	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16636	6543	37	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16637	6484	37	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16641	6415	45	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-16969	6371	37	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-19738	7050	33	Luca and Suciu (eds.) 2011
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-21403	6761	36	Bogaard and Walker 2011
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-21404	6278	37	Bogaard and Walker 2011
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-21405	6868	38	Bogaard and Walker 2011

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Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-21406	6831	37	Bogaard and Walker 2011
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-21407	6767	38	Bogaard and Walker 2011
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-24693	6260	34	Evin *et al.* 2015
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-28790	7113	39	Evin *et al.* 2015
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	OxA-28791	6238	34	Evin *et al.* 2015
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	Poz-52552	7110	40	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	Poz-52553	7060	40	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	Poz-52554	7100	50	Mărgărit *et al.* 2018
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	UBA-18097	6970	27	Balasse *et al.* 2013
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	UBA-18098	6957	28	Balasse *et al.* 2013
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	UBA-9629	7031	29	Balasse *et al.* 2013
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	UBA-9630	7107	29	Balasse *et al.* 2013
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	Wk-14435	6896	61	Mirea 2005
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	Wk-14436	6833	53	Mirea 2005
Măgura-Boldul lui Moș Ivănuș	44.01495	25.408	Romania	Wk-14437	6784	56	Mirea 2005
Maroslele-Pana	46.29959	20.355	Great Hungarian Plain	OxA-9399	6965	50	Whittle *et al.* 2002
Maroslele-Pana	46.29959	20.355	Great Hungarian Plain	OxA-10149	6845	50	Whittle *et al.* 2002
Maroslele-Pana	46.29959	20.355	Great Hungarian Plain	OxA-9401	6780	50	Whittle *et al.* 2002
Maroslele-Pana	46.29959	20.355	Great Hungarian Plain	OxA-9400	6740	50	Whittle *et al.* 2002
Međureč	43.959	21.181	Central Serbia	BRAMS-2251	7316	29	Porčić *et al.* 2021
Međureč	43.959	21.181	Central Serbia	BRAMS-2250	7313	29	Porčić *et al.* 2021
Međureč	43.959	21.181	Central Serbia	BRAMS-2253	7308	29	Porčić *et al.* 2021
Međureč	43.959	21.181	Central Serbia	BRAMS-2254	7266	28	Porčić *et al.* 2021
Međureč	43.959	21.181	Central Serbia	BRAMS-2248	7225	31	Porčić *et al.* 2021
Međureč	43.959	21.181	Central Serbia	BRAMS-2249	7225	31	Porčić *et al.* 2021
Međureč	43.959	21.181	Central Serbia	BRAMS-2247	7212	31	Porčić *et al.* 2021
Međureč	43.959	21.181	Central Serbia	BRAMS-2252	7208	29	Porčić *et al.* 2021
Méhtelek-Nádas	47.92176	22.833	Great Hungarian Plain	Bln-1331	6835	60	Kalicz and Makkay 1977
Méhtelek-Nádas	47.92176	22.833	Great Hungarian Plain	Bln-1332	6655	60	Kalicz and Makkay 1977
Méhtelek-Nádas	47.92176	22.833	Great Hungarian Plain	GrN-6897	6625	50	Kalicz and Makkay 1977
Miercurea Sibiului-point Petriş	45.89777	23.757	Romania	OxA-19739	7131	34	Luca and Suciu (eds.) 2011
Miercurea Sibiului-point Petriş	45.89777	23.757	Romania	GrN-28520	7050	70	Luca and Suciu (eds.) 2011

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Miercurea Sibiului-point Petriş	45.89777	23.757	Romania	Poz-24697	7030	50	Luca and Suciu (eds.) 2011
Miercurea Sibiului-point Petriş	45.89777	23.757	Romania	GrN-29954	7010	40	Luca and Suciu (eds.) 2011
Miercurea Sibiului-point Petriş	45.89777	23.757	Romania	GrN-28521	6920	70	Luca and Suciu (eds.) 2011
Miokovci-Crkvine	43.953	20.249	Central Serbia	BRAMS-2324	7361	28	Porčić *et al.* 2021
Motel Slatina	43.864	21.438	Central Serbia	BRAMS-2334	6291	28	Porčić *et al.* 2021
Motel Slatina	43.864	21.438	Central Serbia	BRAMS-2335	6290	28	Porčić *et al.* 2021
Motel Slatina	43.864	21.438	Central Serbia	BRAMS-2336	6270	28	Porčić *et al.* 2021
Motel Slatina	43.864	21.438	Central Serbia	BRAMS-2337	6360	30	Porčić *et al.* 2021
Motel Slatina	43.864	21.438	Central Serbia	BRAMS-2338	6321	30	Porčić *et al.* 2021
Motel Slatina	43.864	21.438	Central Serbia	BRAMS-2339	6320	28	Porčić *et al.* 2021
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	VERA-3476	7065	35	Raczky *et al.* 2010
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	Poz-23460	7040	40	Gulyas *et al.* 2010.
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	Poz-26328	6970	40	Raczky *et al.* 2010
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	Poz-26327	6940	40	Raczky *et al.* 2010
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	Poz-23317	6890	40	Gulyas *et al.* 2010.
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	VERA-3474	6890	35	Raczky *et al.* 2010
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	Poz-26325	6860	40	Raczky *et al.* 2010
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	VERA-3540	6850	35	Raczky *et al.* 2010
Nagykörű-Tsz Gyümölcsös	47.27454	20.442	Great Hungarian Plain	VERA-3052	6755	40	Raczky *et al.* 2010
Našice Velimirovac – Arenda 1	45.5	18.1	Eastern and norther Croatia	DeA-8335	6855	32	Botić 2016
Našice Velimirovac – Arenda 1	45.5	18.1	Central Serbia	DeA-8336	6704	39	Botić 2016
Novi Sad-Gornja Šuma	45.307	19.809	Vojvodina	BRAMS-2419	6218	27	Porčić *et al.* 2021
Novi Sad-Gornja Šuma	45.307	19.809	Vojvodina	BRAMS-2418	6209	27	Porčić *et al.* 2021
Novi Sad-Gornja Šuma	45.307	19.809	Vojvodina	BRAMS-2417	6192	27	Porčić *et al.* 2021
Obre I	44.1	18.13	Eastern, northern and central Bosnia and Herzegovina	OxA-23289	6390	34	Vander Linden *et al.* 2014
Obre I	44.1	18.13	Eastern, northern and central Bosnia and Herzegovina	OxA-23290	6421	35	Vander Linden *et al.* 2014
Obre I	44.1	18.13	Eastern, northern and central Bosnia and Herzegovina	OxA-23291	6665	35	Vander Linden *et al.* 2014
Obre I	44.1	18.13	Eastern, northern and central Bosnia and Herzegovina	OxA-23292	6432	35	Vander Linden *et al.* 2014
Obre I	44.1	18.13	Eastern, northern and central Bosnia and Herzegovina	UCLA-1605.F	6430	60	Vander Linden *et al.* 2014
Obre I	44.1	18.13	Eastern, northern and central Bosnia and Herzegovina	UCLA-1605.G	6710	60	Vander Linden *et al.* 2014
Obre I	44.1	18.13	Eastern, northern and central Bosnia and Herzegovina	UCLA-1605.I	7240	60	Pinhasi *et al.* 2005
Ocna Sibiului point Triguri	45.87864	24.073	Romania	GrN-28110	7120	60	Luca and Suciu (eds.) 2011

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Ornice-Makrešane	43.614	21.372	Southern Serbia	BRAMS-2223	7335	31	Porčić *et al.* 2021
Ornice-Makrešane	43.614	21.372	Southern Serbia	BRAMS-2220	7233	28	Porčić *et al.* 2021
Ornice-Makrešane	43.614	21.372	Southern Serbia	BRAMS-2217	7225	29	Porčić *et al.* 2021
Ornice-Makrešane	43.614	21.372	Southern Serbia	BRAMS-2218	7190	31	Porčić *et al.* 2021
Ornice-Makrešane	43.614	21.372	Southern Serbia	BRAMS-2219	7161	31	Porčić *et al.* 2021
Ornice-Makrešane	43.614	21.372	Southern Serbia	BRAMS-2221	7143	31	Porčić *et al.* 2021
Ornice-Makrešane	43.614	21.372	Southern Serbia	BRAMS-2224	7081	29	Porčić *et al.* 2021
Ornice-Makrešane	43.614	21.372	Southern Serbia	BRAMS-2222	7033	31	Porčić *et al.* 2021
Parţa-Tell II, communal Sag	45.62809	21.114	Romania	GrN-28459	6660	60	Luca and Suciu (eds.) 2011
Parţa-Tell II, communal Sag	45.62809	21.114	Romania	GrN-28460	6860	60	Luca and Suciu (eds.) 2011
Pavlovac-Gumnište	42.496	21.857	Southern Serbia	BRAMS-2355	6718	28	Porčić *et al.* 2021
Pavlovac-Gumnište	42.496	21.857	Southern Serbia	BRAMS-2358	6664	29	Porčić *et al.* 2021
Pavlovac-Gumnište	42.496	21.857	Southern Serbia	BRAMS-2357	6267	29	Porčić *et al.* 2021
Pavlovac-Gumnište	42.496	21.857	Southern Serbia	BRAMS-2351	6215	29	Porčić *et al.* 2021
Pavlovac-Gumnište	42.496	21.857	Southern Serbia	BRAMS-2350	6155	28	Porčić *et al.* 2021
Perlez-Batka C	45.205	20.389	Vojvodina	OxA-8605	7145	50	Whittle *et al.* 2002
Perlez-Batka C	45.205	20.389	Vojvodina	OxA-10146_duplicate	7100	50	Whittle *et al.* 2002
Perlez-Batka C	45.205	20.389	Vojvodina	OxA-8607	7080	50	Whittle *et al.* 2002
Perlez-Batka C	45.205	20.389	Vojvodina	OxA-8606	6970	50	Whittle *et al.* 2002
Perlez-Batka C	45.205	20.389	Vojvodina	OxA-8597	6935	70	Whittle *et al.* 2002
Pitvaros-Viztározó	46.30028	20.743	Great Hungarian Plain	OxA-9336	7060	45	Whittle *et al.* 2002
Pitvaros-Viztározó	46.30028	20.743	Great Hungarian Plain	OxA-9393	6940	50	Whittle *et al.* 2002
Pitvaros-Viztározó	46.30028	20.743	Great Hungarian Plain	OxA-9392	6885	50	Whittle *et al.* 2002
Podgorač_Ražište	45.46667	18.2	Eastern and northern Croatia	DeA-8339	6413	30	Marković and Botić 2016
Pseće brdo-Bečej	45.618	20.044	Vojvodina	BRAMS-2313	6985	29	Porčić *et al.* 2021
Pseće brdo-Bečej	45.618	20.044	Vojvodina	BRAMS-2306	6805	29	Porčić *et al.* 2021
Pseće brdo-Bečej	45.618	20.044	Vojvodina	BRAMS-2311	6224	28	Porčić *et al.* 2021
Pseće brdo-Bečej	45.618	20.044	Vojvodina	BRAMS-2312	6197	29	Porčić *et al.* 2021
Pseće brdo-Bečej	45.618	20.044	Vojvodina	BRAMS-2309	6148	29	Porčić *et al.* 2021
Râmnicu Vâlcea-point Copăcelu	45.07594	24.337	Romania	KN-I.102	6480	75	Luca and Suciu (eds.) 2011
Ribnjak-Bečej	45.571	20.026	Vojvodina	OxA-8564	6750	65	Whittle *et al.* 2002
Röszke-Lúdvár	46.21454	19.934	Great Hungarian Plain	Deb-2730	6972	59	Horvath and Hertelendi 1994
Rudna Glava	44.317	22.038	Central Serbia	OxA-14623	7198	36	Borić 2009
Rudnik Kosovski	42.795	20.691	Southern Serbia	BRAMS-2413	7343	27	Porčić *et al.* 2021
Safetova Bašča-Gornja Tuzla	44.5601	18.757	Eastern, northern and central Bosnia and Herzegovina	OxA-23296	6593	36	Vander Linden *et al.* 2014
Safetova Bašča-Gornja Tuzla	44.5601	18.757	Eastern, northern and central Bosnia and Herzegovina	OxA-23297	6165	34	Vander Linden *et al.* 2014
Sajan-Domboš	45.841	20.278	Vojvodina	OxA-8566	6815	55	Whittle *et al.* 2002

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Sajan-Domboš	45.841	20.278	Vojvodina	OxA-8567	6780	70	Whittle *et al.* 2002
Sajlovo-lokalitet 5	45.273	19.771	Vojvodina	BRAMS-2426	6721	28	Porčić *et al.* 2021
Sajlovo-lokalitet 5	45.273	19.771	Vojvodina	BRAMS-2425	6211	28	Porčić *et al.* 2021
Šalitrena Pećina	44.191	20.078	Central Serbia	BRAMS-2316	6441	28	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2303	7300	30	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2296	6888	29	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2299	6826	28	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2301	6817	28	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2302	6798	29	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2300	6797	29	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2298	6782	28	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2304	6738	29	Porčić *et al.* 2021
Selište-Sinjac	43.247	22.424	Southern Serbia	BRAMS-2297	6710	28	Porčić *et al.* 2021
Şeuşa-point La Cărarea Morii Alba Iulia	46.04084	23.634	Romania	GrN-28114	7070	60	Luca and Suciu (eds.) 2011
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Beta-318678	6840	40	Botić 2016
Slavonski Brod-Galovo	45.16667	18.05	Croatia	Beta-318679	6860	40	Botić 2016
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	DeA-10051	6908	32	Botić 2016
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	DeA-10052	7033	34	Botić 2016
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	DeA-10055	6766	32	Botić 2016
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	DeA-10057	6816	32	Botić 2016
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	I.R.B.Z._Z-3574	6875	35	Minichreiter and Krajcar Bronić 2006
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	I.R.B.Z._Z-3587	6865	65	Minichreiter and Krajcar Bronić 2006
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Z-3575	6850	60	Minichreiter and Krajcar Bronić 2006
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Z-3588	6820	70	Minichreiter and Krajcar Bronić 2006
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Z-3801	6750	70	Weninger *et al.* 2019
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Z-3922	6709	82	Weninger *et al.* 2019
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Z-3925	6398	67	Weninger *et al.* 2019
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Z-3926	6567	66	Weninger *et al.* 2019
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Z-3927	6659	61	Weninger *et al.* 2019
Slavonski Brod-Galovo	45.16667	18.05	Eastern and northern Croatia	Z-3928	6700	86	Weninger *et al.* 2019
Šljunkara na Dumači	44.73	19.746	Central Serbia	BRAMS-2318	6215	28	Porčić *et al.* 2021

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Sopot	45.25	18.767	Eastern and northern Croatia	Beta-251909	7120	50	Krznarić Škrivanko 2011
Sopot	45.25	18.767	Eastern and northern Croatia	Beta-251911	7110	50	Krznarić Škrivanko 2011
Sopot	45.25	18.767	Eastern and northern Croatia	Beta-251910	7100	50	Krznarić Škrivanko 2011
Sremski Karlovci-Sonje Marinković	45.204	19.93	Vojvodina	BRAMS-2423	7233	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2187	6620	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2188	6611	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2189	6835	29	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2190	6797	29	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2191	6760	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2192	6633	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2194	6701	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2195	6635	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2196	6631	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2197	6665	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2198	6667	28	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2398	6695	27	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2407	6671	27	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2408	6693	27	Porčić *et al.* 2021
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2456	6866	28	Stefanović *et al.* 2019
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2457	6783	27	Stefanović *et al.* 2019
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2458	6851	27	Stefanović *et al.* 2019
Starčevo-Grad	44.822	20.688	Vojvodina	BRAMS-2459	6664	27	Stefanović *et al.* 2019
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-6626	6610	65	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-6629	6615	65	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-7154	6610	100	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-7155	6835	70	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	GrN-8231	6700	70	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-9033	6475	45	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-9034	6640	45	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-9035	6835	45	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-9036	6920	45	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	Grn-9037	6700	55	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	OxA-8559	6565	55	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	OxA-8560	6480	55	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	OxA-8561	6975	60	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	OxA-8562	6730	60	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	OxA-8563	6765	55	Whittle *et al.* 2002
Starčevo-Grad	44.822	20.688	Vojvodina	OxA-8617	6785	55	Whittle *et al.* 2002

Site name	LAT	LON	Region	Lab No	Uncal BP	Standard error	References
Staro selo-Idvor	45.196	20.492	Vojvodina	BRAMS-2199	6614	27	Porčić *et al.* 2021
Staro selo-Idvor	45.196	20.492	Vojvodina	BRAMS-2200	6647	27	Porčić *et al.* 2021
Staro selo-Idvor	45.196	20.492	Vojvodina	BRAMS-2201	6655	27	Porčić *et al.* 2021
Staro selo-Idvor	45.196	20.492	Vojvodina	BRAMS-2202	6658	28	Porčić *et al.* 2021
Staro selo-Idvor	45.196	20.492	Vojvodina	BRAMS-2203	6645	27	Porčić *et al.* 2021
Staro selo-Idvor	45.196	20.492	Vojvodina	BRAMS-2204	6697	31	Porčić *et al.* 2021
Staro selo-Idvor	45.196	20.492	Vojvodina	BRAMS-2205	6635	31	Porčić *et al.* 2021
Staro selo-Idvor	45.196	20.492	Vojvodina	BRAMS-2206	6794	29	Porčić *et al.* 2021
Steierdorf – point Peştera Hoţilor city Anina	45.0167	21.817	Romania	Sac-2001	6710	80	Luca and Suciu (eds.) 2011
Svinjarička Čuka	42.95349	21.67	Southern Serbia	MAMS-34882	6824	31	Horejs *et al.* 2019
Svinjarička Čuka	42.95349	21.67	Southern Serbia	MAMS-34883	7221	31	Horejs *et al.* 2019
Svinjarička Čuka	42.95349	21.67	Southern Serbia	MAMS-34884	6581	29	Horejs *et al.* 2019
Svinjarička Čuka	42.95349	21.67	Southern Serbia	MAMS-40136	6734	25	Horejs *et al.* 2019
Svinjarička Čuka	42.95349	21.67	Southern Serbia	MAMS-40137	6611	24	Horejs *et al.* 2019
Svinjarička Čuka	42.95349	21.67	Southern Serbia	MAMS-40138	6597	24	Horejs *et al.* 2019
Szajol-Felsőföld	47.17009	20.298	Great Hungarian Plain	VERA-3531	6805	35	Raczky 2006
Szajol-Felsőföld	47.17009	20.298	Great Hungarian Plain	VERA-3051	6725	35	Raczky 2006
Szajol-Felsőföld	47.17009	20.298	Great Hungarian Plain	VERA-3534	6620	35	Raczky 2006
Szarvas 23	46.85493	20.584	Great Hungarian Plain	OxA-9375	6855	55	Whittle *et al.* 2002
Szentpéterszeg-Körtvélyes	47.2368	21.594	Great Hungarian Plain	Bln-2578	6800	60	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	Bln-1938	7005	80	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	Bln-1946	7005	80	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	Bln-2576	6940	60	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	Poz-37861	6910	40	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	OxA-23754	6859	34	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	Bln-2577	6790	70	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	Poz-37860	6770	40	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	OxA-23756	6713	33	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	OxA-23755	6713	32	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	OxA-23753	6688	35	Anders and Siklósi 2012
Szolnok-Szanda	47.12019	20.199	Great Hungarian Plain	OxA-23752	6554	32	Anders and Siklósi 2012
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	Deb-11804	6740	60	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	Deb-11890	6920	50	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	Deb-11898	6550	95	Domboroczki 2010

Site name	LAT	LON	Region	Lab No	Uncal BP	Standard error	References
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	Deb-11902	6780	65	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	Deb-12962	6657	65	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	deb-13045	6462	48	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	OxA-20236	6673	35	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	OxA-20237	6776	34	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	OxA-20238	6789	37	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	OxA-20239	6775	40	Domboroczki 2010
Tiszaszőlős-Domaháza-puszta	47.18141	18.988	Great Hungarian Plain	VERA-4243	6245	30	Domboroczki 2010
Tomašanci-Palača	45.39899	18.406	Eastern and northern Croatia	245706	6690	40	Đukić 2020
Tomašanci-Palača	45.39899	18.406	Eastern and northern Croatia	245705	6670	40	Đukić 2020
Tomašanci-Palača	45.39899	18.406	Eastern and northern Croatia	245708	6560	40	Đukić 2020
Tomašanci-Palača	45.39899	18.406	Eastern and northern Croatia	245709	6430	40	Đukić 2020
Tomašanci-Palača	45.39899	18.406	Eastern and northern Croatia	252267	6430	40	Đukić 2020
Tomašanci-Palača	45.39899	18.406	Eastern and northern Croatia	254704	6400	50	Đukić 2020
Topole-Bač	45.384	19.233	Vojvodina	OxA-8693	7170	50	Whittle *et al.* 2002
Topole-Bač	45.384	19.233	Vojvodina	BRAMS-2411	7147	28	Stefanović *et al.* 2020
Topole-Bač	45.384	19.233	Vojvodina	BRAMS-2412	7144	28	Stefanović *et al.* 2020
Topole-Bač	45.384	19.233	Vojvodina	BRAMS-2399	7113	28	Porčić *et al.* 2021
Vinča-Belo Brdo	44.762	20.623	Central Serbia	BRAMS-2593	6552	27	Porčić *et al.* 2021
Vinča-Belo Brdo	44.762	20.623	Central Serbia	MAMS-19518	6499	24	Tasić *et al.* 2015
Vinča-Belo Brdo	44.762	20.623	Central Serbia	MAMS-19519	6746	25	Tasić *et al.* 2015
Vinča-Belo Brdo	44.762	20.623	Central Serbia	OxA-15996	6620	45	Borić 2009
Vinča-Belo Brdo	44.762	20.623	Central Serbia	OxA-28632	6596	34	Tasić *et al.* 2015
Vinča-Belo Brdo	44.762	20.623	Central Serbia	OxA-28633	6626	33	Tasić *et al.* 2015
Vinča-Belo Brdo	44.762	20.623	Central Serbia	OxA-28634	6581	34	Tasić *et al.* 2015
Vinča-Belo Brdo	44.762	20.623	Central Serbia	OxA-28635	6582	33	Tasić *et al.* 2015
Vinča-Belo Brdo	44.762	20.623	Central Serbia	OxA-28636	6665	33	Tasić *et al.* 2015
Vinča-Belo Brdo	44.762	20.623	Central Serbia	OxA-28637	6514	34	Tasić *et al.* 2015
Vinča-Belo Brdo	44.762	20.623	Central Serbia	OxA-28638	6757	34	Tasić *et al.* 2015
Vinkovci – Ervenica, Poljski jarak	45.26667	18.8	Eastern and northern Croatia	BRAMS-2589	6843	27	Penezić *et al.* 2020
Vinkovci – Ervenica, Poljski jarak	45.26667	18.8	Eastern and northern Croatia	BRAMS-2590	6805	27	Penezić *et al.* 2020
Vinogradi-Bečej	45.616	20.033	Vojvodina	OxA-8565	7120	55	Whittle *et al.* 2002

Site name	LAT	LON	Region	Lab No	Uncal BP	Standard error	References
Virovitica-Brekinja	45.83333	17.333	Eastern and northern Croatia	Beta-212603	6470	70	Sekelj-Ivančan and Balen 2007
Vršac-At	45.135	21.306	Vojvodina	OxA-8594	6615	70	Whittle *et al.* 2002
Zadubravlje	45.16667	18.167	Eastern and northern Croatia	Z-2922	6705	95	Weninger *et al.* 2019
Zadubravlje	45.16667	18.167	Eastern and northern Croatia	Z-3929	6673	75	Botić 2016
Zemunica Cave	43.59	16.65	Eastern and northern Croatia	PSUAMS-2224	7030	40	Mathieson *et al.* 2018
Zemunica Cave	43.59	16.65	Eastern and northern Croatia	PSUAMS-2223	7000	40	Mathieson *et al.* 2018
Zemunica Cave	43.59	16.65	Eastern and northern Croatia	PSUAMS-2259	6970	35	Mathieson *et al.* 2018
Zmajevac	44.362	20.962	Central Serbia	BRAMS-2261	7203	28	Porčić *et al.* 2021
Zmajevac	44.362	20.962	Central Serbia	BRAMS-2262	7275	28	Porčić *et al.* 2021
Zmajevac	44.362	20.962	Central Serbia	BRAMS-2263	7231	27	Porčić *et al.* 2021
Zmajevac	44.362	20.962	Central Serbia	BRAMS-2264	7328	27	Porčić *et al.* 2021
Zmajevac	44.362	20.962	Central Serbia	BRAMS-2265	7225	27	Porčić *et al.* 2021
Zmajevac	44.362	20.962	Central Serbia	BRAMS-2266	7283	27	Porčić *et al.* 2021
Zmajevac	44.362	20.962	Central Serbia	BRAMS-2267	7296	27	Porčić *et al.* 2021
Zmajevac	44.362	20.962	Central Serbia	BRAMS-2420	7211	27	Porčić *et al.* 2021
Zmajevo-Livnica	45.457	19.734	Vojvodina	BRAMS-2422	6222	30	Porčić *et al.* 2021
Županja – Dubovo, Košno	45.1	18.667	Eastern and northern Croatia	Z-2973	6530	100	Weninger *et al.* 2019
Županja – Dubovo, Košno	45.1	18.667	Eastern and northern Croatia	Z-3046	6380	100	Weninger *et al.* 2019

References of Appendix

Balasse, M., Bălășescu, A., Janzen, A., Ughetto-Monfrin, J., Mirea, P., Andreescu, R., 2013. Early herding at Măgura-Boldul lui Moş Ivănuş (early sixth millennium BC, Romania): environments and seasonality from stable isotope analysis. *European Journal of Archaeology*, 16 (2), 221-246, DOI:10.1179/1461957112Y.0000000028

Blagojević, T., Stefanović, S. and Porčić, M., 2025. Table with radiocarbon dates from Starčevo–Körös–Criş sites used for palaeodemographic reconstructions [Dataset]. Zenodo. DOI: https://doi.org/10.5281/zenodo.14965881

Bogaard, A., Walker, A., 2011. *Plant use and management at Magura-Buduiasca (Teleor 003), southern Romania: preliminary report on the archaeobotanical analysis*. Report prepared for the European Union, Brussels.

Bogdanović, M., 1994. Prilog proučavanju apsolutne hronologije protostarčevačke i starčevačke kulture. *Starinar*, 47, 187-192.

Botić, K., 2017. *Neolitička naselja na prostoru sjeverne Hrvatske*. Doctoral dissertation, Univerzitet u Zagrebu.

Botić, K., 2018. Middle Neolithic absolute dating in north Croatia – New research. *Studia hereditati universitatis 6*, 1, 89-99, DOI:10.26493/2350-5443.6(1)89-100

Bronk Ramsey, C., Higham, T., Whittle, A.W.R., Bartosiewicz, L., 2007. Radiocarbon chronology. *In:* A.W.R. Whittle, ed. *The Early Neolithic on the Great Hungarian Plain: investigations of the Körös culture site Ecsegfalva 23, County Békés. Varia Archaeologica Hungarica Vol. 21.* Budapest: Institute of Archaeology, Hungarian Academy of Sciences, 173-188.

Cavruc,V., ed., 1998. *Repertoriul arheologic al judeţului Covasna*. Sfântu Gheorghe: Ministreul Culturii, Muzeul Carpaţilor Răsăriteni; Cluj-Napoca: Muzeul Naţional de Istorie a Transilvaniei, Academia Română, Institutul de Arheologie şi Istoria Artei.

Diana, A., Boroneanţ, A., Bălășescu, A., Sava, T., Bonsall, C., 2019. Early Neolithic burials from Grumăzeşti – Deleni, Neamţ County, Romania. *Materiale şi cercetări arheologice*, 15 (1), 15-25, DOI: 10.3406/mcarh.2019.2088

Domboróczki, L., 2010. Report on the excavation at Tiszaszőlős-Domaháza-puszta and a new model for the spread of the Körös culture. *In*: J. K. Kozłowski and P. Raczky eds. *Neolithization of the Carpathian Basin: Northernmost Distribution of the Starčevo/Körös culture: Papers on the Symposium Organized by the EU Projekt FEPRE.* Kraków: Polska Akademia Umiejętności, 137-176.

Domboróczki, L., Raczky, P., 2010. Excavations at Ibrány and the northernmost distribution of the Körös culture. *In*: J. K. Kozłowski and P. Raczky eds. *Neolithization of the Carpathian Basin: Northernmost Distribution of the Starčevo/Körös culture: Papers on the Symposium Organized by the EU Projekt FEPRE*. Kraków: Polska Akademia Umiejętności, 191-218.

Đukić, A., 2020. Tomašanci-Palača – Naselja iz mlađeg kampenog, bakrenog i brončanog doba, *U*: J. Balen, ur. *Naselja starčevačke kulture.* Arheološki muzej u Zagrebu, 19-109.

Evin, A., Flink, L.G., Bălășescu, A., Popovici, D., Andreescu, R., Bailey, D., Mirea, P., Lazăr, C., Boroneanţ, A., Bonsall, C., Vidarsdottir, U.S., 2015. Unravelling the complexity of domestication: a case study using morphometrics and ancient DNA analyses of archaeological pigs from Romania. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370 (1660), 20130616, DOI: 10.1098/rstb.2013.0616

Gulyás, S., Sümegi, P., Molnár, M., 2010. New radiocarbon dates from the Late Neolithic tell settlement of Hódmezővásárhely Gorzsa SE Hungary. *Radiocarbon*, 5212-3, 1458-1464, DOI: 10.1017/S0033822200046543

Horejs, B., Bulatović, A., Bulatović, J., Brandl, M., Burke, C., Filipović, D., Milić, B., 2019. New Insights into the Later Stage of the Neolithisation Process of the central Balkans. First Excavations at Svinjarička Čuka 2018. *Archaeologia Austriaca*, 103, 175-226, DOI: 10.1553/archaeologia103s175

Horváth, F., Hertelendi, E., 1994. Contribution to the 14C based absolute chronology of the Early and Middle Neolithic Tisza region. *Nyíregyházi Jósa András Múzeum Évkönyve*, 36, 111-133.

Jovanović, J., Blagojević, T., Marković, J., Novak, M., Bedić, Ž., Naumov, G., Kanzurova, E.S., Los, D., Hutinec, M., Fidanoski, L., Skelac, G., Šlaus, M., Stefanović, S., 2021. New radiocarbon dates, stable isotope, and anthropological analysis of prehistoric human bones from the Balkans and southwestern Carpathian Basin. *Documenta Praehistorica,* 48, 2-29, DOI: 10.4312/dp.48.18

Kalicz, N., Makkay, J., 1977. *Die Linienbandkeramik in der Grossen Ungarischen Tiefebene. Studia Archaeologica VII*, Budapest.

Kohl, G., Quitta, H., 1966. Berlin radiocarbon measurements II. *Radiocarbon,* 8, 27-45.

Krznarić Škrivanko, M., 2011. Radiokarbonski datumi uzoraka sa Sopota. *U*: M. Dizdar, ur. *Panonski prapovijesni osviti – Zbornik radova posvećen Korneliji Minichreiter uz 65. obljetnicu života.* Zagreb: Institut za Arheologiju, 209-225.

Mantu, C.M., 2000. Relative and absolute chronology of the Romanian Neolithic. *Analele Banatului,* 7-8.

Mărgărit, M., Mirea, P., Radu, V., 2018. Exploitation of aquatic resources for adornment and tool processing at Măgura 'Buduiasca' ('Boldul lui Moş Ivănuş') Neolithic settlement (southern Romania). *Quaternary International*, 472, 49-59, DOI: 10.1016/j.quaint.2017.10.032

Marić, M., 2013. Zaštitna arheološka istraživanja na lokalitetu Jaričište 1. *U*: V. Filipović, R. Arsić R, D. Antonović, ur. *Rezultati novih arheoloških istraživanja u severozapadnoj Srbiji i susednim teritorijama*. Beograd, Valjevo: Srpsko arheološko društvo, Zavod za zaštitu spomenika kulture Valjevo, 17-31.

Marković, Z., Botić, K., 2016. Podgorač, Ražište – rezultati arheoloških istraživanja 2015. godine. *Annales Instituti Archaeologici*, XII, 63-70.

Minichreiter, K., Krajcar Bronić, I., 2006. Novi radiokarbonski datumi rane starčevačke kulture u Hrvatskoj. Prilozi Instituta za Arheologiju u Zagrebu, 23, 5-16.

Mirea, P., 2005. Consideraţii asupra locuirii Starčevo-Criş din sud-vestul Munteniei. *Cultură şi Civilizaţie la Dunărea de Jos*, 22, 37-52.

Oross, K., Bánffy, E., Osztás, A., Marton, T., Nyerges, É.Á., Köhler, K., Szécsényi-Nagy, A., 2016. The early days of Neolithic Alsónyék: the Starčevo occupation. *Bericht der Römisch-Germanischen Kommission,* 94 2013 (2016), 93-121.

Penezić, K., Porčić, M., Urban, P.K., Wittwer-Backofen, U., Stefanović, S., 2020. Stressful times for women-Increased physiological stress in Neolithic females detected in tooth cementum. *Journal of Archaeological Science*, 122, 105217.

Quitta, H., Kohl, G., 1969. Neue Radiokarbondaten zum Neolithikum und zur frühen Bronzezeit Südosteuropas und der Sowjetunion. *Zeitschift for Archäologie*, 3, 223-255.

Raczky, P., 2006. House-structures under change on the Great Hungarian Plain in earlier phases of the Neolithic. *In:* N. Tasić and C. Grozdanov, eds. *Homage to Milutin Garašanin*. Belgrade: Serbian Academy of Sciences and Arts, 379-398.

Raczky P., Sümegi P., Bartosiewicz L., Gál E., Kaczanowska M., Kozłowski J. K., Anders, A., 2010. Ecological barrier versus mental marginal zone? Problems of the northernmost Körös culture settlements in the Great Hungarian Plain. *In:* D. Gronenborn and J. Petrasch, eds. *The Spread of the Neolithic to the central Europe*. International Symposium, Mainz 24 June-26 June 2005 (Offprint). Verlag des Römisch-Germanischen Zentralmuseums Mainz, 147-173.

Sekelj-Ivančan, T., Balen, J., 2007. Brekinja. *U*: D. Sabolić, ur. *Zapadna Virovitička obilaznica – Zaštitna arheološka istraživanja 2005/2006. godine*. Virovitica: Gradski muzej, 19-26.

Stefanović, S., Porčić, M., 2015. Starčevački grobovi na Jaričištu – antropološka analiza. *Arhaika*, 3, 67-88.

Stefanović, S., Petrović, B., Porčić, M., Penezić, K., Pendić, J., Dimitrijević, V., Živaljević, I., Vuković, S., Jovanović, J., Kojić, S., Starović, A., Blagojević, T., 2019. Bone spoons for prehistoric babies: Detection of human teeth marks on the Neolithic artefacts from the site Grad-Starčevo (Serbia). *PLoS One*, 14(12), p.e0225713, DOI: 10.1371/journal.pone.0225713

Stefanović, S., Porčić, M., Blagojević, T., Jovanović, J., 2020. Neolithic settlements in the central Balkans between 6200 and 5300 calBC: issues of duration and continuity of occupation. *In:* N. Tasić, D. Urem-Kotsou, M. Burić, eds. *Making spaces into places. The north Aegean, the Balkans and western Anatolia in the Neolithic*. Oxford: Archaeopress, 191-199.

Tasić, N.N., 1993. Nekoliko novih radiokarbonskih datuma. *Glasnik SAD*, 9, 99-102.

Tasić, N.N., 1997. *Hronologija starčevačke kulture*. Unpublished PhD dissertation, Univerzitet u Beogradu.

Tasić, N.N., Marić, M., Bronk Ramsey, C., Kromer, B., Barclay, A., Bayliss, A., Beavan, N., Gaydarska, B., Whittle, A.W.R., 2015. Vinča-Belo Brdo, Serbia: the times of a tell. *Germania*, 93, 1-75.

Exploring Neolithic site preferences on the River Tisza floodplain using point-pattern analysis and multicomponent environmental models

Michael Kempf, Gerrit Günther, Margaux L.C. Depaermentier

Abstract

The Carpathian Basin, and particularly the River Tisza catchment, is considered a major hub during the transition to a Neolithic lifestyle across Europe. Recent results from interdisciplinary research projects have emphasised the multiple socio-cultural and environmental parameters that shaped and controlled these developments. In this paper, we aim at tracing spatial patterns of Neolithic sites and their temporal variability across the River Tisza floodplain using quantitative methods and spatial analyses. Deploying point-pattern analysis, we present a computational approach to model, visualise, and interpret site distribution as functions of explanatory covariates. The integration of environmental and socio-cultural variables in a multicomponent analysis further makes it possible to distinguish site location parameters and preferences for different time slices and enables the estimation of potential bias by scientific research interest and modern infrastructure.

Keywords: *Carpathian Basin, Neolithic, soil, spatial modelling, point-pattern analysis, quantitative methods, landscape archaeology*

Introduction

The Carpathian Basin is considered a key corridor of the Neolithic expansion into large parts of Europe and an intensive contact and transition zone of long-distance networks between south-eastern and central Europe (Bánffy 2004; Bánffy 2006; Bánffy 2019; Bickle *et al.* 2017; Bickle and Whittle 2013; Raczky 1989; Raczky and Anders 2009; Whittle 2007). A particularly dense pattern of archaeological records has been uncovered since the 1990s, producing a vast database of Neolithic sites

(Bánffy and Raczky 2010; Czifra and Fábián 2016; Wollák and Raczky 2012). Extensive excavations broke new ground in data processing and interpretation, including scientific analyses (Brandt *et al.* 2015; Depaermentier *et al.* 2020; Depaermentier *et al.* 2020; Kreuz *et al.* 2020; Szécsényi-Nagy *et al.* 2014). The post-excavation work, and the recent research programmes in the study area (Anders and Siklósi 2012; Raczky 1995; Raczky 2012), shed new light on the intricacies of intermixing between Balkan groups and the local population, on the various dimensions of the transition to the Neolithic, and on the further evolution of cultural palimpsests over the course of the 6th and 5th millennia BC (Szécsényi-Nagy *et al.* 2014). These processes were now interpreted with the integration of results from aDNA and isotope analyses on human and animal remains to track subsistence strategies, population dynamics, and changes in dietary habits (Brandt *et al.* 2015; Depaermentier *et al.* 2020; Depaermentier *et al.* 2021; Szécsényi-Nagy *et al.* 2014). Furthermore, computational approaches to model, understand, and interpret large site distribution records are used to visualise the dimensions of spatio-temporal developments and to extract underlying (and controlling) patterns that shaped human behaviour.

Here we present a quantitative approach to trace the Neolithic spread across central Europe using multivariate statistics and point-pattern analysis (PPA) of large site databases (Bevan *et al.* 2013; Crema *et al.* 2010; Knitter and Nakoinz 2018). We integrate environmental and socio-cultural variables as explanatory covariates into the analyses to observe whether Early Neolithic, Middle Neolithic, or Late Neolithic site distributions are a function of underlying control mechanisms or whether they are randomly dispersed over the study area. PPA has broadly entered archaeological research and aims at understanding site location patterns, interdependencies, and preferences in the landscape (Baddeley *et al.* 2012; Brandolini and Carrer 2020; Carrero-Pazos 2019; Costanzo *et al.* 2021). Recent results from PPA across Hungary have proven useful to elucidate large spatial transformation processes during the Neolithic and emphasised potential environmental driving factors to control site distribution patterns (Kempf, 2020; Kempf 2021; Kempf & Günther 2023). Building on these results, we considered the River Tisza floodplain and catchment area in eastern Hungary to be highly suitable for a regional analysis due to major site concentrations from the Early Neolithic to the Late Neolithic. We aim at tracing the Middle to the Late Neolithic transition in spatial site location parameters.

Material and Methods

The archaeological dataset underlying the analyses was provided by Dr. Attila Kreiter from the Hungarian National Museum at Budapest and is a subset of a larger data sample (Kempf 2021). The data contains various information regarding site chronology, name, id, and 'cultural occupation'. We distinguished the point data into three major Neolithic periods, covering the Early Neolithic, Middle Neolithic and Late Neolithic. These broad chronological references allow for pattern recognition on large temporal scales, in particular between Middle Neolithic and Late Neolithic, instead of down-scaling to single 'cultural' periods attributed by pottery styles or long-standing traditional 'material culture' (Hofmann *et al.* 2021). In total, the dataset within the extent of the study area comprises 374 Early Neolithic sites, 1038 Middle Neolithic sites, and 193 Late Neolithic sites. This database, however, represent a current state of research and does not reflect a chronologically 'realistic' picture of the Hungarian archaeology. We want to emphasise the model character of this paper that is based on temporality of the data and the methods used during investigation. Furthermore, databases are usually an amalgamate of long-standing tradition, different scientific approaches, and revised chronological artefacts and thus can never be considered methodologically free from bias.

Archaeological site database issues

The archaeological database of Hungary, however, cannot be considered free from bias. Long-standing scientific research and focus have created artificial densities of, for example, Early Neolithic sites from extensive survey activities. Furthermore, the close distance to university hubs can influence the outreach of survey and excavation activity and create a lively archaeological scene – fuelling the local interest in archaeology. In addition, the construction of motorways and infrastructural links in Hungary produced multiple survey and digging efforts that contributed to the regional depth of archaeological site distribution in the River Tisza region.

Another issue of PPA in general and for this paper in particular is the point data structure of the database. Archaeological sites cannot be considered zero-dimensional or at best two-dimensional objects but rather multi-dimensional polygons with spatial and temporal depth. Particularly sites that show a large chronological variability – usually referred to as site continuity – are tricky to evaluate in terms of location parameters as site controlling factors. What is referred to as 'continuity', however, is rather a chronological development of a specific environmentally or socio-culturally suitable area that experienced long occupation due to resource availability or affordance of the respective group. These, on the other side, are subject to the respective period, the political agenda, and environmental conditions in the very moment of occupation and thus are highly dynamic and subject to constant transformations. Site continuity is rather a construct of area continuity, in which multiple polygons from different occupation phases are added on top of another to create the continuously occupied 'site'. From this polygon, centroids were created to fit into a site database. Eventually, chronological site information is added to the coordinates in longitude/latitude format. However, the resulting point data are spatially disconnected from the chronologically corresponding polygon due to generalisation during area definition. This leads to considerable uncertainties during the analysis of site distribution patterns when one merely focuses on covariates underlying the point data. This paper, however, uses a focal approach of the covariates and integrates environmental as well as archaeological explanatory factors within specific complementary regions around each site. This prevents the simple assumption that site preferences are only controlled by the information provided in one point. One has to keep in mind that we are not working on a micro-scale focusing on individual buildings, but on multiple and rather uncertain settlement locations in the whole Tisza region. Therefore, we use environmental datasets and a digital elevation model with a resolution of 100 m × 100 m, or 10 000 m², and a focal statistics approach for the analysis. The focal approach creates a raster dataset in which the output value of each cell location is a function of the input raster value at that cell location and the cell values within a specified neighbourhood around the cell. This means, that a cell is assigned the mean value of the cells in a 1 km radius for elevation, slope and aspect as well as a 5 km radius for the different soil types. Hence, a cell in the output raster used for the analysis is the function of 10 or 50 neighbourhood cells. Thus, we aim to take into account, that an archaeological settlement does not consist of a single location in a database, but rather of an area.

Environmental settings

The study area covers the Hungarian part of the drainage basin of the River Tisza and its major tributaries (Fig. 1). To the west, the spatial extent is constrained by the extensive sandy plains of the Danube – Tisza Interfluve (DTI) (Ladányi *et al.* 2015; Mádl-Szőnyi *et al.* 2008; Nyári *et al.* 2007). Towards the northern part, the Great Hungarian Plain is limited by the North-Hungarian Range and the outcrops of the

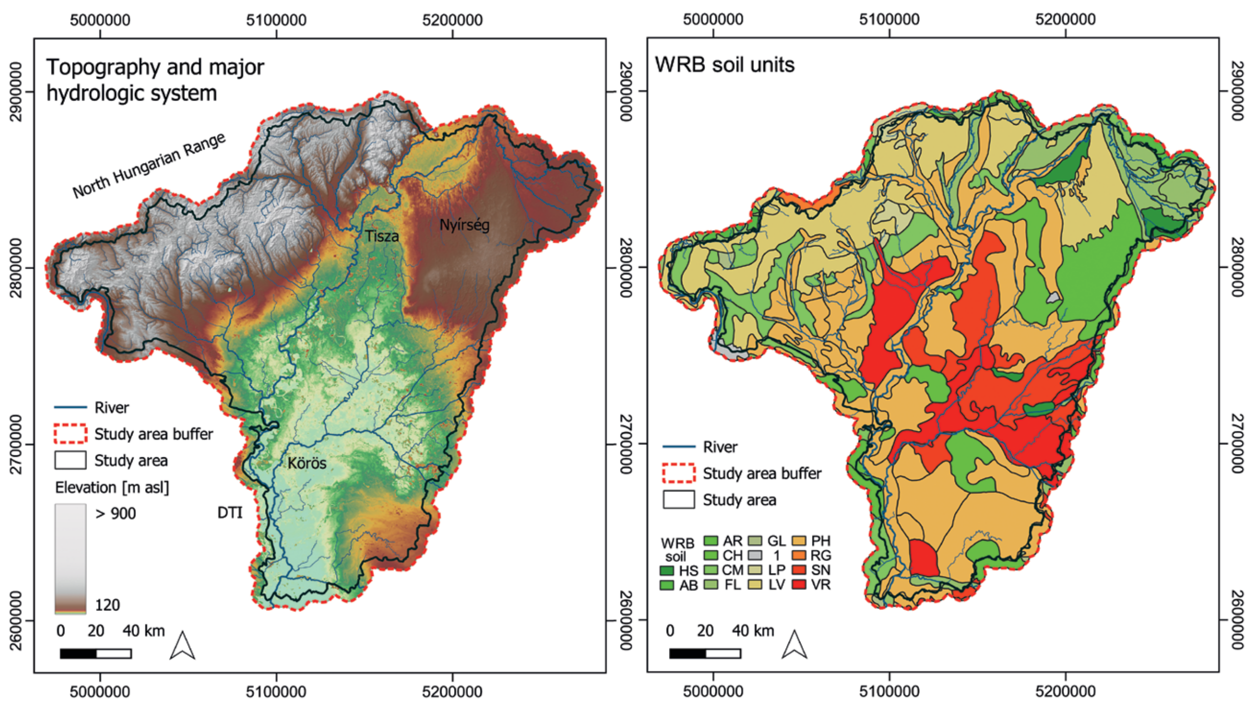


Figure 1. Topography, major hydrological system, and WRB soil units of the River Tisza floodplain and catchment area in Hungary (see Table 1 for WRB soil unit abbreviations).

Mátra, Bükk, Cserehát and Tokaj mountains. To the north-east, the floodplain of the River Tisza merges into the Nyírség, a sandy plateau that rises over the floodplain. Draining the entire eastern part of the Carpathian Basin, the river deposited massive alluvial fans with fragmented palaeo-channels (Kasse *et al.* 2010; Kiss *et al.* 2015; Magyari 2011; Moskal-del Hoyo *et al.* 2018; Timár *et al.* 2005). Avulsion events (massive channel outbreaks) have constantly changed the riverbed and led to cut-off sandy plateaus, which were covered with loess during the Pleistocene. Prior to large flood protection measures during the 19th and 20th centuries, the River Tisza was particularly prone to flash floods and extensive flooding caused by heavy rainfall events in the catchment area (Borsos and Sendzimir 2018; Guida *et al.* 2015).

PPA and first-order effects

PPA is a statistical analysis that aims to detect if a spatial point pattern shows spatial trends, *e.g.* if it is clustered, regularly dispersed, or random (Gatrell *et al.* 1996). Clustered site behaviour results from the attraction of specific features, such as other sites. In archaeological research, push and pull factors between sites, site centrality, and a generated surplus of meaning of a site in relation to its complementary region has been, for example, worked out recently by Nakoinz (2019). Resource distribution, such as fertile cropland and freshwater access further adds multi-dimensional variables into the production of site patterns and increases the complexity of potential interpretation.

In general, the above-mentioned approaches are referred to as *first-order* and *second-order properties* (Bailey and Gatrell 1995; Gatrell *et al.* 1996). First-order properties are described as the intensity of a process in relation to an external covariate, such as the number of sites within a specific area and an environmental explanatory variable. The point's location is influenced by the underlying area's structure but not by the location of other points (Wiegand and Moloney 2004). The second-order properties describe inherent spatial dependency (Eve and Crema 2014), like attraction or repulsion and occur when the location of a point is

influenced by the presence or absence of other points (Wiegand and Moloney 2004). Point-pattern analyses are common in ecological studies (Legendre and Legendre, 2012; Wiegand and Moloney 2013) and have increasingly entered archaeological research (Brandolini and Carrer 2020; Carrero-Pazos 2019; Crema *et al.* 2010).

Ripley's inhomogeneous K function was applied to test the point patterns for complete spatial randomness (CSR) (Dixon 2002; Marcon *et al.* 2013; Nakoinz and Knitter 2016). The major focus of this operation lies on the detection of interaction concentrations, which are mirrored in the performance of sequential nearest-neighbour analysis, including kernel density estimation (KDE) and Monte Carlo simulations (Baxter *et al.* 1997; Hewitt *et al.* 2020; Vanacker *et al.* 2001). With these operations, the spatial properties of a point pattern can be analysed. The function evaluates whether the observed point pattern is different from a theoretical distribution (Bevan and Conolly 2006; Crema *et al.* 2010; Nakoinz and Knitter 2016; Orton 1982). The calculated envelope represents by default two standard deviations, that is 95% of the cases in normal distributed cases (Fig. 2). If the empirically observed data lies below the theoretical, the distribution is regularly dispersed. Otherwise, the data are clustered. These differences can be visualised in a density map of the point pattern (KDE). A KDE map is the result of an intensity analysis, which measures the expected number of points per unit area (Baddeley *et al.* 2016, 160). That makes it possible to track observation frequencies in the sample within a specified geographic extent. Eventually, the interpolation over all values provides a smoothed visualisation of the point pattern at a specific radius (Fig. 2).

Environmental datasets

In this article we focus on soil composition and units, the hydrologic network, and topographical features for the analysis of spatial patterning in the archaeological record. We included focal statistics into the analyses, which represent a summed-up data representation of a specific catchment around each site. To conduct the analyses, data preparation includes homogenisation, harmonisation, and categorisation to produce comparable results. In this section, a brief overview of the workflow is presented, followed by the statistical layout that enables the analyses.

Topography

A digital elevation model (TanDEM-X 90m Digital Elevation Model, © DLR 2022 (German Aerospace Center 2018)) was downloaded from the German Aerospace Center (DLR) and resampled to a 100 m grid resolution. The digital elevation model (DEM) was cropped to the study area, including a 5 km buffer to avoid edge effects during the PPA (Baddeley and Turner 2005). Elevation values and slope gradients come in continuous data ranges and were further processed using focal statistics (Hijmans 2022). To estimate the preferences for certain aspects of the site locations during each chronological period, we distinguished four cardinal directions: North (315-45°), East (45-135°), South (135-225°), and West (225-315°).

Hydrology

Hydrologic streamflow datasets were downloaded from the European Environment Agency (EEA, European catchments and rivers network system (Ecrins)). The data were categorised via the Strahler stream order number (1-8). Using variable radii, the lines were buffered to avoid corner-connected cells during the rasterisation process (Conolly and Lake 2006). Here, we use 2.5, 5, 7.5, 10, 15, 20, 25, and 37.5 m radii for the respective Strahler number. The polygons were dissolved and rasterised to a 100 m cell size.

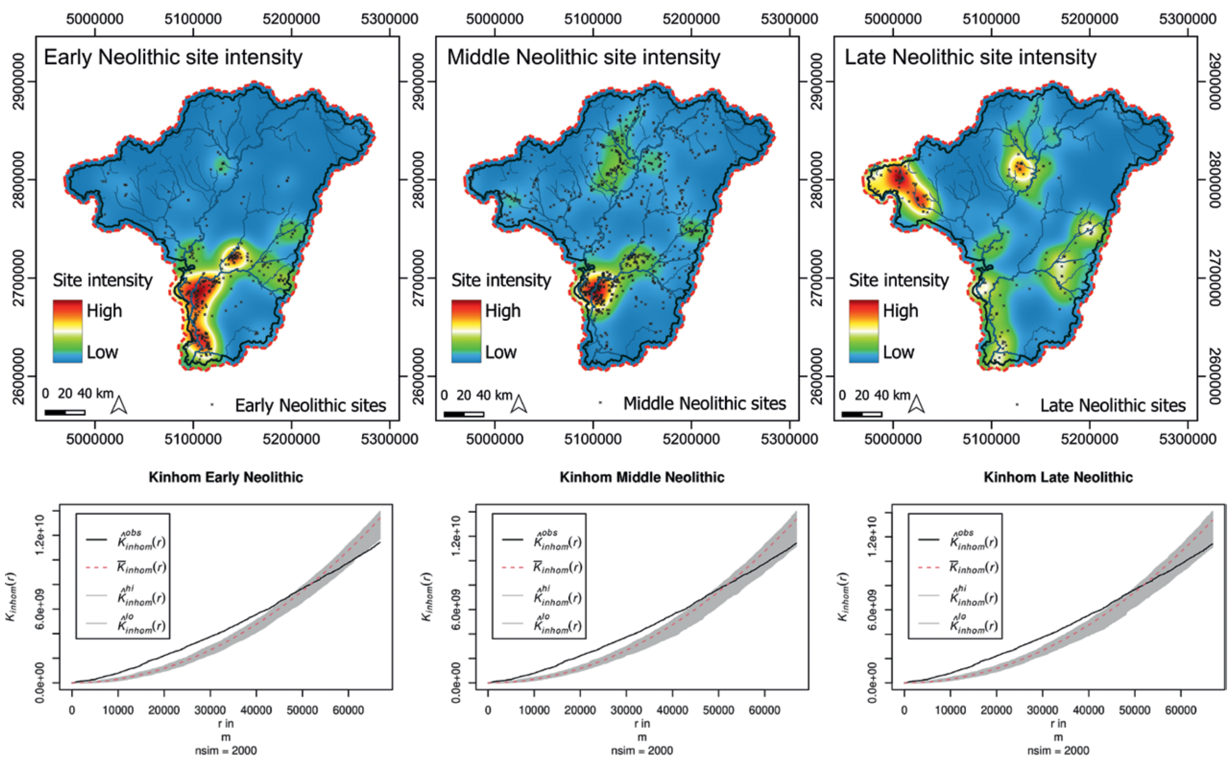


Figure 2. Site distribution pattern and intensity analysis of Early Neolithic, Middle Neolithic, and Late Neolithic sites in the study area. KDE with sigma=10 km for each chronological subset (upper part). Ripley's inhomogeneous K function for Early Neolithic, Middle Neolithic and Late Neolithic, showing the clustered site behaviour (lower part).

Soil

Soil data were acquired from the Joint Research Center – European Soil Data Center (ESDAC, https://esdac.jrc.ec.europa.eu/) (Panagos *et al.* 2012). In this study, we used the European Soil Database v2.0, which can be downloaded upon request from the ESDAC repository and comes in shapefile format, including the WRB soil reference system classification (World Reference Base for Soil Resources). We distinguished 14 different soil classes (Table 1).

PPA and multicomponent covariate analyses (first-order effects)

One potential approach to measure the influence of environmental or socio-cultural variables is to model site intensity as a function of an underlying explanatory covariate (Baddeley *et al.* 2016; Brandolini and Carrer 2020; Laabs and Knitter 2021; Kempf 2021). The site dataset comes in two-dimensional, geographically defined format. Solely adding a z-value to a point does not comprehensively describe the composition of the catchment of a site in terms of variation in the covariate parameters. For this reason, the first-order PPA presented in this article includes a focal approach, which makes each cell of a covariate a function of the entire catchment in a defined neighbourhood (Hijmans 2022; Kempf 2020; Kempf 2021; Knitter and Nakoinz 2018).

Focal statistics of environmental covariates

Calculations and analyses are conducted using the R environment and the packages dplyr (Wickham et al. 2022), maptools (Bivand and Lewin-Koh 2021), raster (Hijmans 2022), sf (Pebesma 2018), sp (Pebesma and Bivand 2005), spatstat (Baddeley and Turner 2005), and stars (Pebesma *et al.* 2022). Focal statistics were

calculated, in which the values of the neighbouring cells were included into the calculation of each cell in a moving window. Here, we defined a radius of 5000 m for the single soil and the hydrologic Strahler data, and a radius of 1000 m for slope, elevation, and aspect.

Site intensity as function of underlying environmental covariates

We take the spatial patterns of environmental parameters to test site intensities against background variability. To do so, we use the spatstat package in R (Baddeley et al. 2016) and the implemented function rhohat to calculate site intensity as a function of the preprocessed focal raster data. With this approach, we can visualise the effect of attraction or repulsion given by a specific parameter in a defined catchment. We can estimate the correlation between site intensity and a variable in a 95% confidence envelope (Baddeley *et al.* 2012).

Site distribution as function of previous sites

We can further identify trends or interdependencies between two or more point patterns. Here, we use the KDE of one sample as an explanatory covariate of another. This allows us to draw conclusions about spatio-chronological links, site continuity, and potential spatial transitions between periods. The KDE of Early Neolithic sites is compared to the point pattern of Middle Neolithic and the KDE of Middle Neolithic is compared to the pattern of the Late Neolithic.

Results and discussion

The results from our model allow us to determine, which parameters underlie site distribution patterns. However, we want to emphasise that these estimates are part of the theoretical model, which includes both inductive (empirical) data and a deductive assumption that Neolithic sites are clustered in areas with high environmental suitability as settlement spots with complementary hinterlands. The 'tickmarks' at the horizontal axis of the presented plots are the observed sites corresponding to each parameter value (Baddeley 2018, 55). If there is a high intensity of sites, the tickmarks form a block, indicating clustering in the range of the respective covariate (*e.g.* a specific soil unit). Peaks in the curve indicate high density compared to the nearest surrounding, however, the confidence interval determines the significance of the intensity. A large envelope points towards lower confidence and hence describes single values or clustered outlier behaviour. High site intensity and small confidence intervals show high significance and, in this case, strong preference of a particular value range of the covariate.

Topography

During the Early Neolithic, a preference for lowland sites between 100 and 200 m in elevation is visible, which is higher than what László Bartosiewicz (2013) observed a decade ago (mean=79.4 ± 7.6 m), though his study focused on the Middle Tisza region. Sites between about 220 and 300 m were less preferred, and higher altitudes were avoided. During the Middle Neolithic, a similar preference for sites between 100 and 250 m in altitude becomes evident. Sites can also be found up to an altitude of around 700 m, which would reflect the expected shift towards higher locations during the Middle Neolithic (Gulyás *et al.* 2020). However, the frequency decreases with increasing altitude. The trend towards an increase of sites in regions up to 700 m altitude does not continue during the Late Neolithic. Here, sites around 150 to 250 are preferred and sites above 300 m were sparse.

Identifier	WRB-LEV1	HSC	Suitability	Area (%)	EN	MN	LN
AB	Albeluvisol/Retisol	Alluvial/sandy soil	low	0.11	0	0	0
AR	Arenosol	Skeletal soil, sandy soils	low	4.41	1	2	0
CH	Chernozems	Chernozem	very high	6.18	7	43	6
CM	Cambisol	Meadow/brown forest soil	medium-high	7.61	24	58	24
FL	Fluvisol	Alluvial soil	high	6.23	8	30	6
GL	Gleysol	meadow soil	low	0.24	0	0	6
HS	Histosol	Peat soil	low	1.64	2	9	2
LP	Leptosol	Lithomorphic soil	very low	0.93	0	5	0
LV	Luvisol	Brown forest soil	very high	16.71	8	68	24
PH	Phaeozem	Chernozem, meadow soil	very high	37.14	172	502	78
RG	Regosol	Skeletal soil	low	0.03	0	0	0
SN	Solonetz	Salt-affected soil	very low	8.72	74	151	27
VR	Vertisol	Meadow soils	medium	9.61	78	167	20
'1' (?)	/	Meadow soil	medium	0.45	0	3	0
					374	1038	193

Table 1. Soil distribution in the study area with WRB soil reference system, Hungarian references (HSC), and agricultural potential. Numbers of Early Neolithic (EN), Middle Neolithic (MN) and Late Neolithic (LN) sites in each soil class (Kempf 2020; Krasilnikov and Michélí 2009; Michéli et al. 2006).

There is a clear preference for sites that are oriented between 120° and 250° (southern or south-western direction) throughout all three periods. Only a small number of sites are oriented between 80° and 120° (eastern direction) or between 250° and 300° (western direction). None of the sites are oriented between 0° and 80° or 300° and 360° (north-eastern to north-western direction). The broad confidence envelopes, however, indicate an uncertainty, increasing from southern or south-western direction to north-eastern and north-western orientation for all periods.

Higher slope gradients are considered unsuitable for agricultural purposes (Bevan and Conolly 2004) and in the study area, the total number of sites located directly on slopes > 12° are max. 1% (Early Neolithic 0/374; Middle Neolithic 11/1038; Late Neolithic 1/193). A preference for sites that were located on slopes between 0° and 5° can be observed for all three periods. During the Middle Neolithic and Late Neolithic, steeper slopes were also settled on, but the site frequency decreases with increasing slope. During the Early Neolithic, the narrow confidence envelope for sites on slopes up to 1° suggests a high certainty for sites in this slope range. The broader envelope between 1° and 2° points to a slightly higher uncertainty for this range. The single spikes of 2.5° or more indicate single sites on corresponding slopes with a high uncertainty. The narrow confidence envelope, fluctuating around the average intensity, further indicates a generally high probability of sites on slopes between 0° and 10° during the Middle Neolithic. The confidence envelope slightly starts to broaden from this point on, indicating an increasing uncertainty with increasing slopes. In contrast, the confidence interval for sites with a slope of about 1.5° or more is much wider during the Late Neolithic. This points to a higher uncertainty for sites on steeper slopes (Fig. 3).

Soil preferences

14 different soil types were analysed for site preferences during the Neolithic (Fig. 4). Most of the sites cannot be considered equally distributed across the study area. Due to their very small spatial extent, these soil types did not play a major role as location parameters. Here, we focus on soils that show clear preference or evident avoidance of a particular soil unit.

Albeluvisol
No sites are directly located on AB, and the site intensity analysis of the catchment composition indicates no abundance of AB soils within a 5 km radius around all sites. This mirrors the general very low percentage of AB soils in the study area (0.11%).

Arenosol
AR soils show less than 1% of site locations and their share in the catchment is very small (Table 1). A minor frequency of AR soils can be found at the margins of Middle Neolithic sites, but they do not play a major role as location parameters due their abundance of less than 5% in the study area. Both, AB and AR soils are considered skeletal, lithomorphic and sandy soils and are not considered a high agricultural potential (Fig. 4.a).

Chernozem
CH soils do not make up a large percentage of the study area (6.18%) (Table 1) and play a minor role during the Early Neolithic and Late Neolithic, also considering the catchment composition. CH soil patches that fall into the 5 km catchment are significantly located at the margins. During the Middle Neolithic, there is increased variability in the catchment composition. However, from 1038 Middle Neolithic sites, only 4.14% are directly located on chernozem soils and considering the site intensity trend towards lower values, which indicate avoidance in close distance to the sites, an overall preference of loess-influenced CH soils can be excluded (Fig. 4.b).

Cambisol
CM soils make up about 7.6% (Table 1) of the soil units in the study area and Early Neolithic (6.4%), Middle Neolithic (5.6%), and Late Neolithic (12.4%) sites only show direct preferences for CM soils during the Late Neolithic. The site intensity with CM in the catchment increases during the Middle Neolithic with greater variation from the mean value (red dashed line in the rhohat plot). During the Late Neolithic, this variation decreases, which results in a smoothed intensity confidence envelope and high probability at low and lower probability at high values. That means that low proportions of CM soils (value 0) are more likely to be found in the catchment than larger CM patches (value 1). The peak towards 1 represents the 12.4% of sites that are located directly on CM soils (Fig. 4.c).

Fluvisol
The rather fertile fluvisols are comparable to the alluvial soils of the HSC and make about 6.23% of the total soil types in the study area (Table 1). Mostly, this soil type is abundant in the northern and north-eastern part of the study area along the upper parts of the River Tisza and its tributaries. The site ratio is rather low, there are only 2.1% (Early Neolithic), 2.9% (Middle Neolithic), and 3.1% (Late Neolithic) sites located on fluvisols. The site-catchment analysis further confirms the unimportance of this soil type as catchment component within a 5 km distance around the sites (Fig. 4.d).

Gleysol
This soil type is represented only in very small fragments across the study area. One particular patch is located between two neighbouring cambisol units in the north-western part and corresponds spatially to a meadow that is drained by several tributaries of the River Ipeľ, which enters the River Danube at Chľaba (Slovakia). Due to their rather unsuitable conditions for agriculture without intensive drainage, gleysols did not play a decisive role as location parameter in the catchment composition.

Histosol
Histosols are considered to form under anoxic and waterlogged conditions and show very high organic content. Particularly the waterlogging and the high pH make

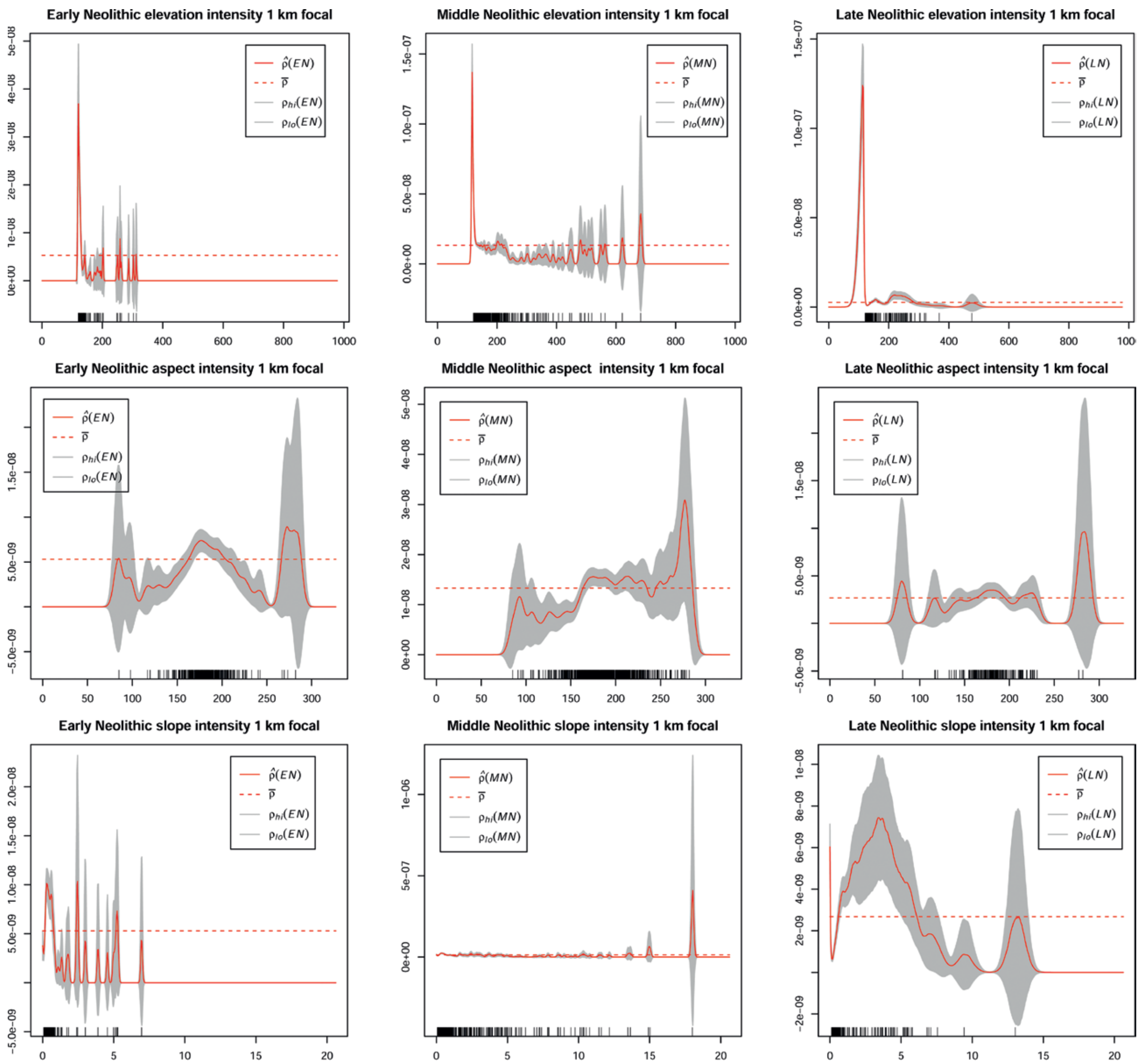


Figure 3. Site intensity as function of the explanatory covariates elevation (upper part), aspect (middle part), and slope gradient (lower part).

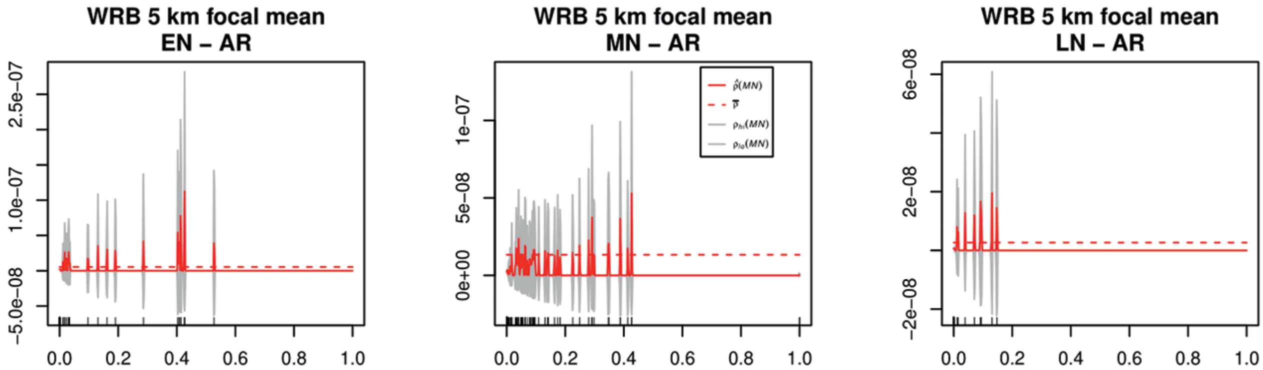
them unsuitable for agricultural purposes. During the Early Neolithic and Late Neolithic, peat soils or Histosols did not play any role as a location parameter and were clearly avoided. The variation during the Middle Neolithic lies under the theoretical distribution and can be considered random.

Leptosol

This soil type represents lithomorphic soils in the HSC and is abundant only in the very northern part of the study area (< 1%) (Table 1). Leptosols show a generally low agricultural potential due to their high stoniness, thin humus layer, and low water storage capacity. In combination with very small spatial frequency in the study area, this soil is considered of minor importance during the Neolithic.

Luvisol

Luvisol corresponds to brown forest soil in the HSC and is mostly abundant to the northern and hilly margins of the study area. These soils can demonstrate a high fertility and suitability for agriculture. However, only 2.1% (Early Neolithic), 6.6% (Middle Neolithic), and 12.4% (Late Neolithic) of the sites are directly located on luvisol, compared to a general distribution of 16.71% in the study



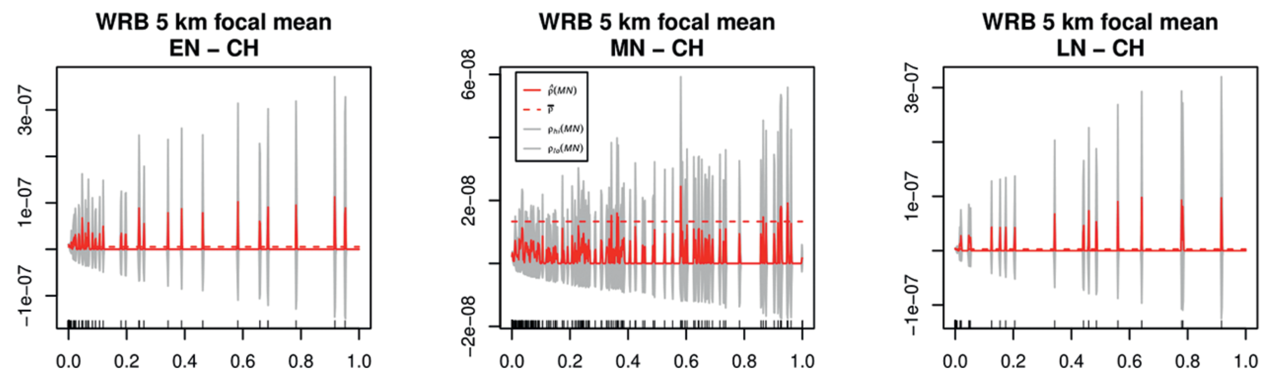


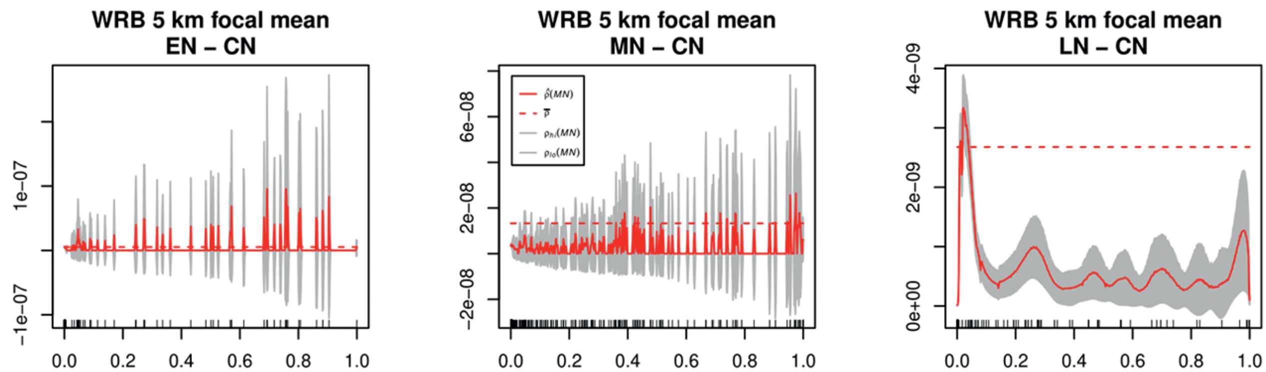
Figure 4a (top). Arenosol site preferences cannot be observed in the study area.

Figure 4b (bottom). Chernozem site preferences in the study area can be excluded.

area. This can be explained by simultaneous occurrences in higher elevated areas with larger slope gradients that are nowadays forest-covered. Although generally suitable, these parameters prevent agricultural exploitation. The large variation in the 5 km catchment area analysis and the overall abundance particularly in the Middle Neolithic and the Late Neolithic represents the spatial shift towards the northern part of the study area during the Neolithic. Another explanation could be the introduction of new agricultural tools and techniques like the use of ox-drawn ard and simple plough in the Middle Neolithic and their improvement in the Late Neolithic, which could have facilitated the use of heavier soils such as forest soils (Milisauskas and Kruk 2011). Sites that are located in the valleys show considerable amounts of luvisol in the study area, which could have served as cropland, depending on the slope gradient (Fig. 4.e).

Phaeozem

Phaeozems are distributed across the entire study area and make over 37% of the total soil types (Table 1). Humid conditions and high fertility characterise this soil type at the interface between steppe soil and forest soil. Spatially, the distribution of WRB phaeozems is comparable to chernozem and meadow soils in the HSC, making it particularly difficult to determine the origin and development of this soil type. The abundance in rather humid areas along the streamflow and the strong diversity within a small distance probably emphasise a similar starting point chernozems from previous humid phaeozems or meadow soils. The overall high suitability is visible in the strong preference for these soils in the catchment composition and further as direct location parameter. 46% (Early Neolithic), 48% (Middle Neolithic), and 40% (Late Neolithic) sites are located on phaeozem and there is a further high site intensity with phaenozem at all distances around the sites – particularly during the Middle Neolithic. Surprisingly, there is also a significant tendency towards very low values, which indicates a clear avoidance of phaeozems in the catchment. During the Early Neolithic and Middle Neolithic, this is connected to the soil types along



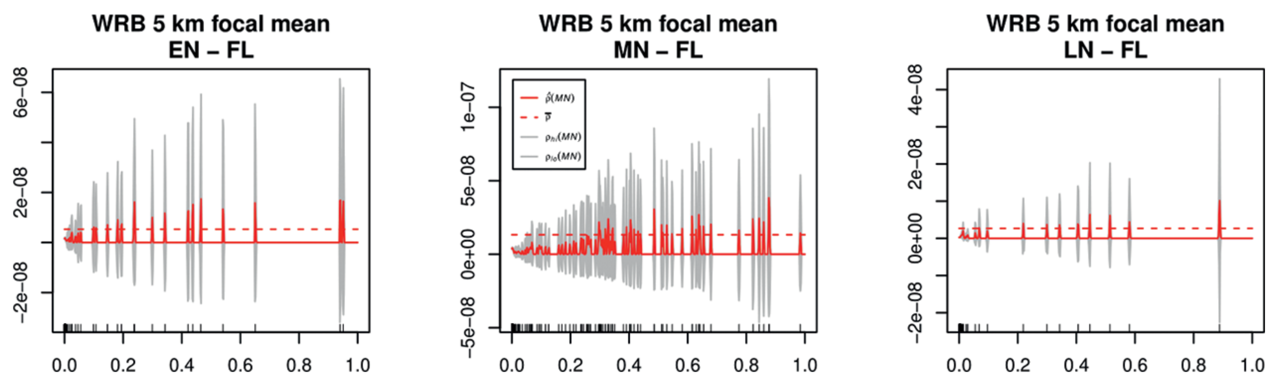


Figure 4c (top). Cambisol site preferences can only be observed during the Late Neolithic.

Figure 4d (bottom). Fluvisols did not play a decisive role as location parameter during the Neolithic in the study area.

the River Körös and its tributaries, where vertisols and meadow soils (HSC) are mostly abundant. The site intensity in this region, however, is most likely biased by the strong research interest during the 20th century (Fig. 4.f).

Regosol

With only 0.3% abundance in the study area (Table 1), this soil type does not play a significant role as location parameter.

Solonetz

These soil types are salt-affected soils and represent the third most abundant type in the study area (8.72%) (Table 1). Compared to the HSC, these soils fall into the categories salt-affected soils and meadow soils. However, there is a clear spatial difference between the rather salt-affected soils in the northern SN patches (River Hortobágy) and the more meadow soil character in the southern area of the SN distribution (River Berettyó; both rivers are tributaries to the River Körös). Due to this spatial distribution, the Early Neolithic and the Middle Neolithic shows high site intensities connected to salt-affected soils. This relationship can be biased due to the above-mentioned parameters. On the other hand, the importance of salt exploitation during the Neolithic has been frequently discussed by multiple authors, thus emphasising potential use of salt marshes for cattle breeding (Bánffy 2015; Harding 2015; Harding *et al.* 2013). The spatial shift during the Late Neolithic towards the northern part of the study area would then result in lower frequency of salt-affected soils in the catchment due to lower abundance. Still, the total number of sites on SN soil types is around 14% during the Late Neolithic, compared to 19.8 % (Early Neolithic), and 14.6% (Middle Neolithic) (Fig. 4.g).

Vertisol

This soil type makes up 9.61% of the total study area (Table 1) but shows a strong preference during the Early Neolithic (20.9%) and the Middle Neolithic (16%). The catchment analysis highlights the importance as location parameter during these chronological periods. The increased variation during the Late Neolithic corresponds

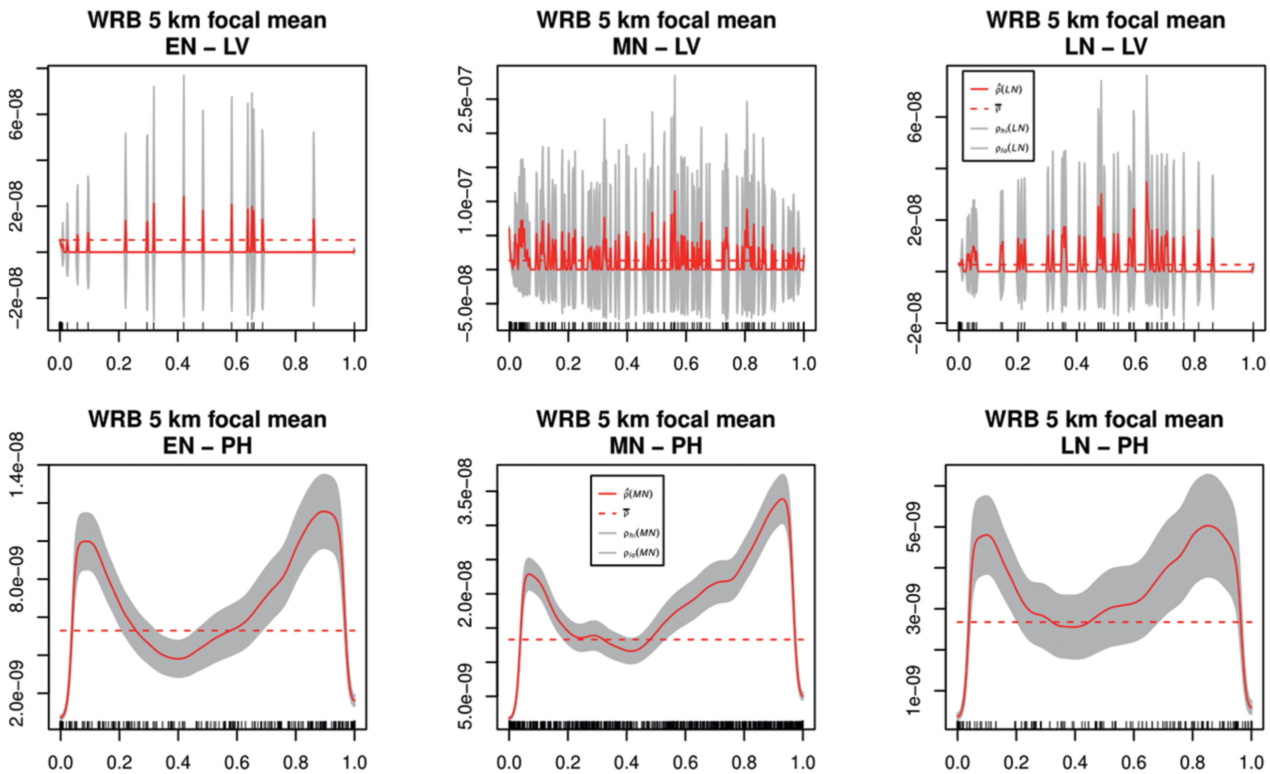


Figure 4e (top). Site intensity as functions of luvisol distribution in the study area.

Figure 4f (bottom). Site intensity as a function of Phaeozem distribution in the study area.

with only 10.4% of all sites, emphasising neither preference nor avoidance. Similarly, to the SN soils, the local density of VR soils in the River Körös catchment and the site intensity in this region can bias the results of this analysis. On the other hand, this region is considered the core area of the Early Neolithic Körös 'cultural group', thus pointing towards the high importance of this area for the agricultural spread. In general, vertisols are considered a poor agricultural potential due to waterlogging and high clay content. Spatially, the VR corresponds to the meadow soils in the HSC, which points towards a higher suitability for crop production than the WRB would assume. Even though modern land-use strategies cannot be compared to prehistoric patterns, the area shows strong modern agricultural exploitation. However, this can most likely be linked to strong drainage activity during the past two centuries and does not necessarily account for premodern conditions (Fig. 4.h).

WRB '1' (?) Md soil
This soil represents an artefact in the WRB reference system and characterises very small meadow (?) soil patches in the northern margins of the study area. Most likely, these remnants stem from spatial merging processes. They play no significant role in the analysis.

Hydrology

The importance of freshwater access has often been labelled decisive for prehistoric settlement locations (Hedges *et al.* 2013; Kreuz 2007; Sielmann 1972; Whittle 2007). Here, we refer to this distance-based relationship as a function of the proportion of water availability within the catchment. Instead of simply measuring the closest streamflow, we evaluate the weighted water abundance using the Strahler order numbers of the major rivers and their tributaries in the study area. In this approach, the calculated rhohat functions represent two things that risk intermixing: the site intensities are plotted in combination with water intensity values, thus giving an

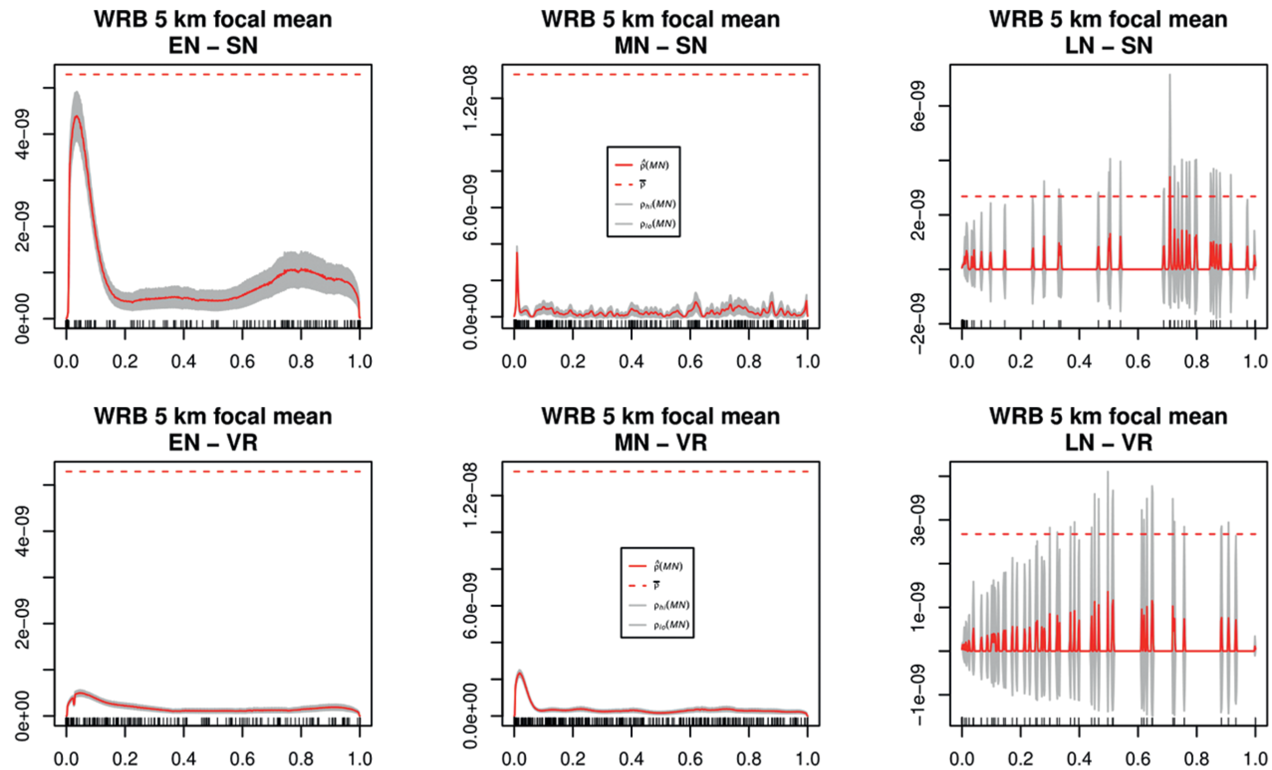


Figure 4g (top). Salt-affected soils can be considered a preferable catchment component, particularly during the Early Neolithic.

Figure 4h (bottom). Vertisol abundance in the catchment compositions during the Neolithic.

idea of how far or how close each site is located to major stream courses. The higher the values, the more likely the sites are located close to a river of high Strahler order number. The lower the values, the more likely the sites are located far from a major river or at some distance to a smaller Strahler order number streamflow. Hence, a lower value does not necessarily mean that the site is not having direct access to fresh water but that it is located in considerable distance to the major hydrologic network. To cross-check whether the relationship is stronger between sites and the major or the minor Strahler order rivers, we simply measured the number of sites that fall into a variable distance buffer around particular values.

The highest Strahler order, 8, shows 4, 15 and 23 Early Neolithic; 11, 28 and 44 Middle Neolithic; and 3, 9 and 11 Late Neolithic sites within 500 m, 1000 m and 1500 m distance, respectively, within these buffers. That indicates that the close distance to the large river network was less important than having small tributaries within the catchment. However, the number of small-scale rivers is rapidly increasing towards the headwaters of the larger river systems and consequently, the number of sites that fall into close distance to one of these smaller currents increases accordingly. The measures for the Early Neolithic and the merged Strahler order numbers 1-3 within the same buffers are 59, 89, and 114. For the Middle Neolithic even more, 240, 331, and 401 and finally for the Late Neolithic 59, 78, and 102 sites, making over 50% located in regions with small-scale headwaters. This has two implications for the interpretation of freshwater access as a location parameter: first, large-scale river networks in the study area have a high risk of severe and extensive flooding and cannot be considered primary location parameters despite the related advantages such as water availability, biodiversity, and fertile soils. This supports the results of the archaeo-malacological analysis led by Sándor Gulyás and colleagues in the region (Gulyás *et al.* 2020). Second, small-scale rivulets were more attractive as a site location. Regarding the Early Neolithic, not only the general environmental and hydrological conditions, but also a minor change in climatic conditions known as the IRD 5.b event, which led to wetter climatic conditions, and particularly during the main precipitation period in

summer, and more frequent and intensified flood events in the Carpathian Basin, is considered to have reduced the area available for settlement and agricultural activities (Gronenborn 2010; Gulyás *et al.* 2020; Kreuz *et al.* 2020).

These observations, however, must be seen in close relationship to the spatial shift of sites during the Late Neolithic and the denser patterns towards the northern parts of the Carpathian Basin, which has a higher density of headwater streams (Fig. 5).

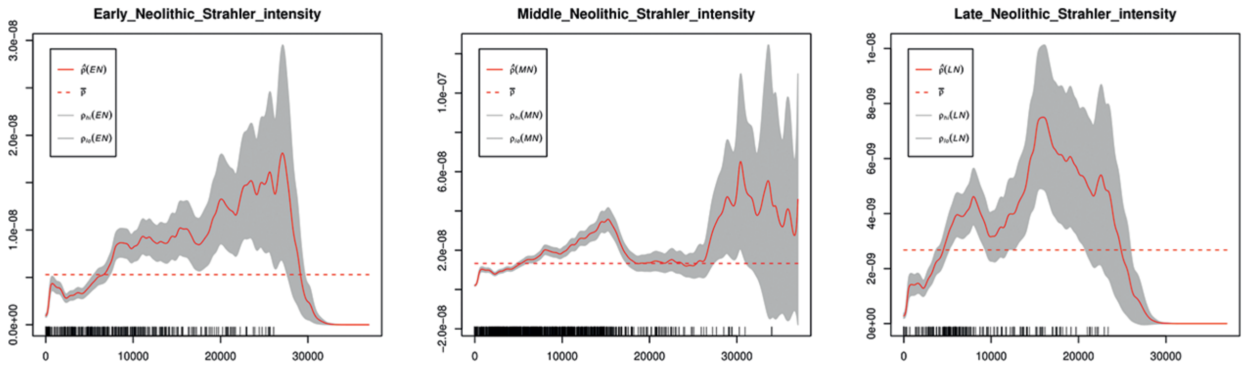
Site continuity and chronological transformation

From visual interpretation of the KDE (Fig. 2), spatial continuity in the Lower Tisza floodplain can be expected. However, the covariate analysis of the Middle Neolithic sites as a function of Early Neolithic site densities clearly shows that there is a considerable site distribution with values close to zero – emphasising that there are differences between Early Neolithic and Middle Neolithic 'core areas' and that Middle Neolithic sites are not entirely a function of previous sites. There is a clear signal that new and previously unoccupied areas were now inhabited and that the slight shift to the north, which is visible in the KDE, is in fact much more prominent than expected from visual interpretation. However, the far larger sample size of Middle Neolithic sites compared to Early Neolithic sites needs to be considered a potential bias in the analysis. This trend becomes more evident during the Late Neolithic, which is clearly not a function of Middle Neolithic site distribution. The few outliers are plotted with very large uncertainty envelopes and cannot be considered to show clustered behaviour. The majority of sites are located at low values with small confidence band, indicating high site intensity in areas previously not occupied by Middle Neolithic sites. As expected, the Late Neolithic site distribution is further not considerably influenced by Early Neolithic site densities (Fig. 6).

The analyses show that the spatial shift between the Middle Neolithic and the Late Neolithic is evident. Furthermore, the KDE alone does not provide sufficient information about site intensity shifts, and changes among the spatial distribution of sites at different periods cannot be observed on a visual basis alone. Hence, the *rhohat* function provides a suitable method to estimate site development on broad chronological scales and to identify spatial patterns in combination with a KDE.

Neolithic settlement and land-use strategies

The KDEs indicate strong spatial shifts between all Neolithic periods with a more prominent geographical change between the Middle Neolithic and the Late Neolithic (Fig. 2). It is usually acknowledged that the Körös culture expanded stepwise from the Balkans to Hungary from 6000 cal BP onwards. It reached the River Körös and the Middle Tisza region around 5900-5850 cal BC and the Upper Tisza Region between 5770 and 5530 cal BC (Domboróczki 2010; Raczky *et al.* 2010). In this context it is generally assumed that the Körös cultural group did not expand further north in the middle of the 6th millennium BC due to unsuitable ecological settings for an agricultural system based on Mediterranean species and traditions (Bartosiewicz 2013; Gulyás *et al.* 2020). This climatic, pedologic, and vegetation boundary, which is also perceived as an important contact zone between farmers and foragers (Bánffy 2013), is labelled as the Central European Balkanic Agroecological Barrier (Sümegi 2004, 2008). From the Middle Neolithic onwards, the increased requirement for non-occupied land on the one hand, and the introduction of new agricultural techniques, of new crops and plants, and maybe also the decrease in the hunter-gatherer population on the other, might



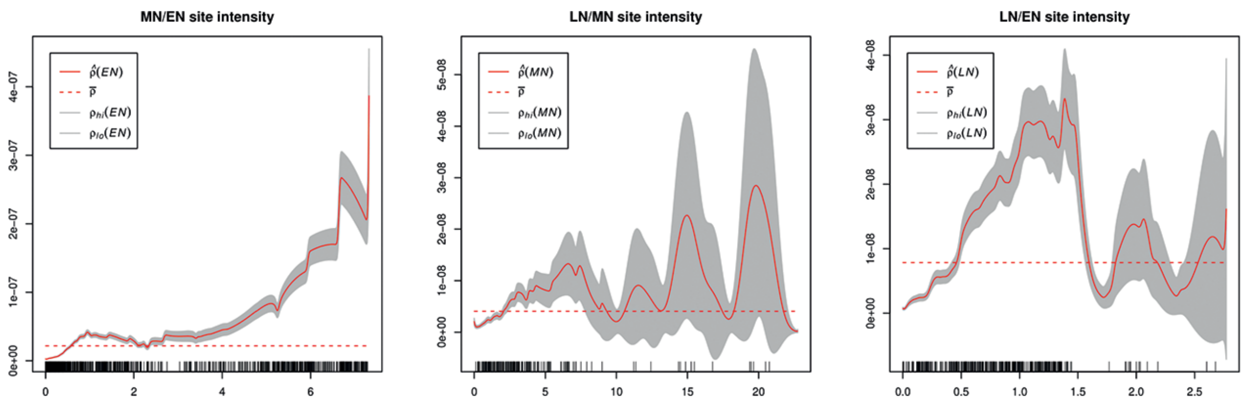


Figure 5 (top). Site intensity as a function of distance to running fresh water and hydrologic composition of the catchment.

Figure 6 (bottom). Site intensity as a function of previous site densities. MN/EN shows Middle Neolithic sites as a function of Early Neolithic site intensity, LN/MN shows Late Neolithic sites as function of Middle Neolithic site intensity, and LN/EN shows Late Neolithic sites as function of Early Neolithic site intensity.

have encourage the spread of the farmer communities towards new areas (Kreuz *et al.* 2020; Milisauskas and Kruk 2011). This geographical shift, which is also reflected in a shift in site distribution *(e.g.* on higher location or different soils), is concomitant with an increase in settlement complexity and diversity, a change in subsistence strategies (with more animal husbandry instead of opportunistic hunting and fishing), and a higher diversity in diet (Gulyás *et al.* 2020; Hernando *et al.* 2021; Milisauskas and Kruk 2011; Parkinson 2002). Some of these settlement areas were then abandoned during the Late Neolithic and settled again during the Early Copper Age (Parkinson 2002). The shift in settlement strategies from the NL onwards can partly be associated with an increase in social hierarchy (Milisauskas and Kruk 2011; Parkinson 2002), but also with an increase in cattle husbandry and herd's size, which requires larger grazing areas, and the increased role of animal by-products (like wool, milk, manure, and also traction) – a phenomenon labelled as the 'secondary products revolution' (Sherratt 1981; see also Bökönyi 1988; Milisauskas and Kruk 2011). However, isotope analyses rather reveal a locally organised Late Neolithic society (Depaermentier *et al.* 2020; Giblin 2009; Giblin *et al.* 2013) and a small-scale livestock management, excluding transhumance in the Great Hungarian Plain (Hoekman-Sites and Giblin 2012).

Site continuity and database bias assessment

Empirical data can be biased by a variety of influencing factors, and in particular, data on the distribution of archaeological sites can be strongly influenced by modern land use and the density of archaeological research activity, including rescue excavations. It is therefore necessary to reconcile the patterns that emerge from the distribution of archaeological sites with the modern extent of rural and urban agglomerations, residential areas, and infrastructure networks, as well as with the reasons for excavation activity. As mentioned above, excavation activity in Hungary is generally characterised by the increasing number of rescue

excavations and the simultaneous decreasing time for planning, preparation, and execution of excavations. This has led to a general mismatch between archaeological departments and institutions and investors and 'land developers' throughout (and not limited to) Hungary. From this point of view, the whole country has experienced massive changes in land cover, which have favoured the discovery of many archaeological features, but have also created – at least in part – an artificial archaeological distribution. However, some regions of Hungary show a denser distribution of sites than others, which could be due to more intensive survey activity and research projects (*e.g.* the Körös Region Archaeology Project (Gyucha *et al.* 2012) or the Upper Tisza Project (Gillings 1995)), construction activity, or a truly denser archaeological record. Most likely, this is, however, due to another problem in the Hungarian Archaeology Database, as reported by Attila Kreiter: In Hungary, documentary evidence of excavation activity is part of museums, heritage departments, and university infrastructure due to legal regulations of state or government institutions (Kreiter 2021). Eventually, this leads to a massive regionalisation of the digital density of the archaeological record due to the fact that provision of digital data to a centralised archaeological database governed by the Hungarian National Museum in Budapest is fully voluntary (this is, however, not a Hungarian issue alone, considering, for example, the insufficient archaeological database management structure of Germany's federal heritage departments).

Perspectives

Computational methods in archaeology can be successfully used to analyse spatial behaviour of archaeological site distributions and enable us to draw conclusions about site preferences in the landscape. The here applied approach using PPA can be considered a major advance in quantitative archaeology to discover the catchment compositions of archaeological sites. The major benefit lies in the spatial configuration of the analyses and the variable distances that can be included using the R programming language. However, the data we analyse is modern data and thus represents a bias itself – a major problem of archaeological large-scale analysis in general and landscape archaeology in particular. Another important issue that needs to be raised using environmental data in combination with archaeological samples is the interdisciplinary approach that is indispensable for the analysis to determine the correct explanatory variables and to understand the links and feedbacks of ecological parameters. Thus, we emphasise the importance of cross-discipline cooperation in our field to gain new results that allow for new interpretations.

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References

Anders, A. and Siklósi, Zs., eds., 2012. *The Körös culture in eastern Hungary*. International Series 2334. Oxford: Archaeopress.

Baddeley, A., 2018. A Statistical Commentary on Mineral Prospectivity Analysis. *In:* Daya Sagar, B.S., Cheng, Q. and Agterberg, F., eds. *Handbook of Mathematical Geosciences.* Cham: Springer International Publishing, 25-65.

Baddeley, A. and Turner, R., 2005. spatstat: An R Package for Analyzing Spatial point Patterns. *Journal of Statistical Software*, 12(6). DOI: 10.18637/jss.v012.i06

Baddeley, A., Chang, Y.-M., Song, Y. and Turner, R., 2012. Nonparametric estimation of the dependence of a spatial point process on spatial covariates. *Statistics and Its Interface*, 5, 221-236.

Baddeley, A., Rubak, E. and Turner, R., 2016. *Spatial point patterns: Methodology and applications with R*. (A Chapman & Hall book). Boca Raton: CRC Press Taylor & Francis Group.

Bailey, T.C. and Gatrell, A.C., 1995. *Interactive spatial data analysis*. Harlow: Longman.

Bánffy, E., 2004. *The 6th millennium BC boundary in western Transdanubia and its role in the central European transition (the Szentgyörgyvölgy-Pityerdomb settlement)*. Varia Archaeologica Hungarica, 15. Budapest.

Bánffy, E., 2006. Eastern, Central and Western Hungary – variations of Neolithisation models. *Documenta Praehistorica*, 33, 125-142. DOI: 10.4312/dp.33.13

Bánffy, E., 2013. Tracing the Beginning of Sedentary Life in the Carpathian Basin: The Formation of the LBK House. *In:* Hofmann, D. and Smyth, J., eds. *Tracking the Neolithic house in Europe,* New York: Springer Science, Business Media, 117-149.

Bánffy, E., 2015. The beginnings of salt exploitation in the Carpathian Basin (6th-5th millennium BC), *Documenta Praehistorica*, 42(15), DOI: 10.4312/dp.42.13

Bánffy, E., 2019. *First Farmers of the Carpathian Basin: Changing patterns in subsistence, ritual and monumental figurines*. Oxford, Philadelphia: Oxbow books

Bánffy, E. and Raczky, P., 2010. The crisis and changes in cultural heritage legislation in Hungary: cul-de-sac or solution? *In:* Schlanger, N. and Aitchison, K., eds. *Archaeology and the global economic crisis: Multiple impacts, possible solutions.* Tervuren: Culture Lab Editions, 81-86.

Bartosiewicz, L., 2013. Early Neolithic Fishing in the Middle Tisza region, Hungary, *Archeofauna*, 22, 133-144.

Baxter, M.J., Beardah, C.C. and Wright, R., 1997. Some Archaeological Applications of Kernel Density Estimates. *Journal of Archaeological Science*, 24(4), 347-354. DOI: 10.1006/jasc.1996.0119

Bevan, A. and Conolly, J., 2004. GIS, Archaeological Survey, and Landscape Archaeology on the Island of Kythera, Greece. *Journal of Field Archaeology*, 29(1-2), 123-138. DOI: 10.1179/jfa.2004.29.1-2.123

Bevan, A. and Conolly, J., 2006. Multiscalar Approaches to Settlement pattern analysis. *In:* Lock, G. and Molyneaux, B.L., eds. *Confronting Scale in Archaeology: Issues of Theory and Practice.* New York: Springer, 217-234.

Bevan, A., Crema, E. R., Li, X. and Palmisano, A., 2013. Intensities, Interactions and Uncertainties: Some New Approaches to Archaeological Distributions. *In:* Bevan, A. and Lake, M., eds. *Computational Approaches to Archaeological Spaces.* Walnut Creek: Left Coast Press, 23.

Bickle, P. and Whittle, A.W.R. eds., 2013. *The first farmers of central Europe: Diversity in LBK lifeways*. Oakville, CT: Oxbow Books and the David Brown Book Company (Cardiff Studies in Archaeology).

Bickle, P., Cummings, V., Hofmann, D. and Pollard, J., eds., 2017. *The Neolithic of Europe: Papers in honour of Alasdair Whittle*. Oxford: Oxbow Books.

Bivand, R. and Lewin-Koh, N., 2021. *maptools: Tools for Handling Spatial Objects* (Version R package version 1.1-2). Available from: https://cran.r-project.org/web/packages/tmaptools/index.html.

Bökönyi, S., 1988. *A History of Domestic Animals in central and eastern Europe*, Budapest: Akadémiai Kiadó.

Borsos, B. and Sendzimir, J., 2018. The Tisza River: Managing a Lowland River in the Carpathian Basin. *In:* Schmutz, S. and Sendzimir, J., eds. *Riverine Ecosystem Management.* Cham: Springer International Publishing, 541-560.

Brandolini, F. and Carrer, F., 2020. Terra, Silva et Paludes. Assessing the Role of Alluvial Geomorphology for Late-Holocene Settlement Strategies (Po Plain – N Italy) Through Point Pattern Analysis. *Environmental Archaeology*, 1-15. DOI: 10.1080/14614103.2020.1740866

Brandt, G., Szécsényi-Nagy, A., Alt, K. W. and Haak, W., 2015. Human paleogenetics of Europe. The known knowns and the known unknowns. *Journal of Human Evolution*, 79, 73-92.

Carrero-Pazos, M., 2019. Density, intensity and clustering patterns in the spatial distribution of Galician megaliths (NW Iberian Peninsula). *Archaeological and Anthropological Sciences*, 11(5), 2097-2108. DOI: 10.1007/s12520-018-0662-2

Conolly, J. and Lake, M., 2006. *Geographical Information Systems in Archaeology*. Cambridge: Cambridge University Press.

Costanzo, S., Brandolini, F., Idriss Ahmed, H., Zerboni, A. and Manzo, A., 2021 Creating the funerary landscape of eastern Sudan. *PLoS One*, 16(7), DOI: 10.1371/journal.pone.0253511

Crema, E.R., Bevan, A. and Lake, M.W., 2010. A probabilistic framework for assessing spatio-temporal point patterns in the archaeological record. *Journal of Archaeological Science*, 37(5), 1118-1130. DOI: 10.1016/j.jas.2009.12.012

Czifra, Sz. and Fábián, Sz., 2016. Towards a new horizon: development-led large scale excavation policy in Hungary post-1990's. *In:* Horňák, M., Guermandi, M. P.; Stäuble, H.; Depaepe, P.; Novaković, P.; Demoule, J. P.., eds. *Recent developments in preventive archaeology in Europe: Proceedings of the 22nd EAA Meeting in Vilnius, 2016.* Ljubljana: Znanstvena založba Filozofske fakultete; Birografika Bori, 219-231.

Depaermentier, M.L.C., Osztás, A., Bánffy, E., Alt, K.W. and Kempf, M., 2020. Neolithic land-use, subsistence, and mobility patterns in Transdanubia: A multiproxy isotope and environmental analysis from Alsónyék – Bátaszék and Mórágy – Tűzkődomb. *Journal of Archaeological Science: Reports*, 33(17). DOI: 10.1016/j.jasrep.2020.102529

Depaermentier, M.L.C., Kempf, M., Bánffy, E. & Alt, K.W., 2020. Tracing mobility patterns through the 6th-5th millennia BC in the Carpathian Basin with strontium and oxygen stable isotope analyses, *PLoS One*. DOI: 10.1371/journal.pone.0242745

Depaermentier, M.L.C., Kempf, M., Bánffy, E. and Alt, K.W., 2021. Modelling a scale-based strontium isotope baseline for Hungary. *Journal of Archaeological Science*, 135, DOI: 10.1016/j.jas.2021.105489

Dixon, P.M., 2002. Ripley's K function. *In:* El-Shaarawi, A.H. and Piegorsch, W.W., eds. *Encyclopedia of environmetrics.* Chichester: Wiley, 1796-1803.

Domboróczki, L., 2010. Neolithization in northeastern Hungary: old theories and new perspectives. *In:* Gronenborn, D. and Petrasch, J., eds. *Die Neolithisierung Mitteleuropas. The Spread of the Neolithic to central Europe.* Mainz: Verlag des Römisch-Germanischen Zentralmuseums, 175-184.

Eve, S.J. and Crema, E.R., 2014. A house with a view? Multi-model inference, visibility fields, and point process analysis of a Bronze Age settlement on Leskernick Hill (Cornwall, UK). *Journal of Archaeological Science*, 43, 267-277. DOI: 10.1016/j.jas.2013.12.019

Gatrell, A. C., Bailey, T. C., Diggle, P. J. and Rowlingson, B. S., 1996. Spatial Point Pattern Analysis and Its Application in Geographical Epidemiology. *Transactions of the Institute of British Geographers*, 21(1), 256-274.

German Aerospace Center, 2018. *TanDEM-X – Digital Elevation Model (DEM) – Global, 90m*.

Gillings, M., 1995. Flood dynamics and settlement in the Tisza Valley of north-east Hungary: GIS and the Upper Tisza project. *In:* Lock, G. and Stančič, Z., eds. *Archaeology and Geographical Information Systems: A European Perspective*, London: Taylor and Francis, 67-84

Gronenborn, D., 2010. Climate, crises and the 'neolithisation' of central Europe between IRD-events 6 and 4. *In:* Gronenborn, D. and Petrasch, J., eds. *Die Neolithisierung Mitteleuropas. The Spread of the Neolithic to central Europe.* Mainz: Verlag des Römisch-Germanischen Zentralmuseums, 61-80.

Guida, R. J., Swanson, T. L., Remo, J. W. and Kiss, T., 2015. Strategic floodplain reconnection for the Lower Tisza River, Hungary: Opportunities for flood-height reduction and floodplain-wetland reconnection. *Journal of Hydrology*, 521, 274-285. DOI: 10.1016/j.jhydrol.2014.11.080

Gulyás, S., Nagy, B., Sümegi, P., Schöll-Barna, G. and Demény, A., 2020. Intensified mid-Holocene floods recorded by archeomalacological data and resilience of first farming groups of the Carpathian Basin. *Archaeological and Anthropological Sciences*, 12(8).

Gyucha, A., Yerkes, R.W., Parkinson, W.A., Sarris, A., Papadopoulos, N., Duffy, P.R., Salisbury, R.B., 2012. Settlement Nucleation in the Neolithic: A Preliminary Report of the Körös Regional Archaeological Project's Investigations at Szeghalom-Kovácshalom and Vésztő-Mágor. *In:* Hansen, S.; Raczky, P.; Anders, A. and Reingruber, A., eds. *Neolithic and Copper Age between the Carpathians and the Aegean Sea. Chronologies and Technologies from the 6th to the 4th Millennium BCE*. Bonn: Dr. Rudolf Habelt GmbH.

Harding, A., 2015. Salt exploitation in the later prehistory of the Carpathian Basin. *Documenta Praehistorica,* (42), 211-217.

Harding, A., Kavruk, V. and Bukowski, K., 2013. *Explorations in salt archaeology in the Carpathian Zone*. (Archaeolingua, 28). Budapest: Archaeolingua Alapítvány.

Hedges, R., Bentley, R. A., Bickle, P., Cullen, P., Dale, C., Fibiger, L., Hamilton, J., Hofmann, D., Nowell, G. and Whittle, A.W.R., 2013. The supra-regional perspective. *In:* Bickle, P. and Whittle, A.W.R., eds. *The first farmers of central Europe: Diversity in LBK lifeways.* Oxford: Oxbow Books and the David Brown Book Company.

Hernando, R., Gamarra, B., McCall, A., Cheronet, O., Fernandes, D., Sirak, K., Schmidt, R., Lozano, M., Szeniczey, T., Hajdu, T., Bárány, A., Kalli, A., Tutkovics, E. K., Köhler, K., Kiss, K., Koós, J., Csengeri, P., Király, Á., Horváth, A., Hajdu, M. L., Tóth, K., Patay, R., Feeney, R. N. M. and Pinhasi, R., 2021. Integrating buccal and occlusal dental microwear with isotope analyses for a complete paleodietary reconstruction of Holocene populations from Hungary. *Scientific reports*, 11(1), 7034.

Hewitt, R.J., Wenban-Smith, F.F. and Bates, M.R., 2020. Detecting Associations between Archaeological Site Distributions and Landscape Features: A Monte Carlo Sim-

ulation Approach for the R Environment. *Geosciences*, 10(9), 326. DOI: 10.3390/geosciences10090326

Hijmans, R.J., 2022. *raster: Geographic Data Analysis and Modeling* (Version R package version 3.5-15). Available from: https://cran.r-project.org/package=raster

Hoekman-Sites, H.A. and Giblin, J.I., 2012. Prehistoric animal use on the Great Hungarian Plain: A synthesis of isotope and residue analyses from the Neolithic and Copper Age. *Journal of Anthropological Archaeology*, 31(4), 515-527.

Hofmann, D., Hanscam, E., Furholt, M., Bača, M., Reiter, S., S., Vanzetti, A., Kotsakis, K., Petersson, H., Niklasson, E., Hølleland, H. and Frieman, C. J., 2021. Forum: Populism, Identity Politics, and the Archaeology of Europe. *European Journal of Archaeology*, 24(4), 519-555. DOI: 10.1017/eaa.2021.29

Kasse, C., Bohncke, S.J.P., Vandenberghe, J. and Gábris, G., 2010. Fluvial style changes during the last glacial – interglacial transition in the middle Tisza Valley (Hungary). *Proceedings of the Geologists' Association*, 121(2), 180-194. DOI: 10.1016/j.pgeola.2010.02.005

Kempf, M., 2020. Neolithic land-use, landscape development, and environmental dynamics in the Carpathian Basin. *Journal of Archaeological Science: Reports*, 34, 102637. DOI: 10.1016/j.jasrep.2020.102637

Kempf, M., 2021. Take a seed! Revealing Neolithic landscape and agricultural development in the Carpathian Basin through multivariate statistics and environmental modelling. *PLoS One*, 16(10), e0258206. DOI: 10.1371/journal.pone.0258206

Kempf, M. and Günther, G., 2023. Point pattern and spatial analyses using archaeological and environmental data – A case study from the Neolithic Carpathian Basin. *Journal of Archaeological Science: Reports*, 47. DOI: 10.1016/j.jasrep.2022.103747

Kiss, T., Hernesz, P., Sümeghy, B., Györgyövics, K. and Sipos, Gy., 2015. The evolution of the Great Hungarian Plain fluvial system – Fluvial processes in a subsiding area from the beginning of the Weichselian. *Quaternary International*, 388, 142-155. DOI: 10.1016/j.quaint.2014.05.050

Knitter, D. and Nakoinz, O., 2018. Point Pattern Analysis as Tool for Digital Geoarchaeology: A case study of Megalithic Graves in Schleswig-Holstein, Germany. *In:* Siart, C., Forbriger, M. and Bubenzer, O., eds. *Digital geoarchaeology: New techniques for interdisciplinary human-environmental research.* (Natural Science in Archaeology). Cham, Switzerland: Springer, 45-64.

Krasilnikov, P.V. and Michélí, E., 2009. Soil Classification of Hungary. *In:* Krasilnikov, P., Ibanez Marti, J.-J., Arnold, R., Shoba, S. eds. *A Handbook of Soil Terminology, Correlation and Classification.* Sterling (USA): Earthscan, 170-175.

Kreiter, A., 2021. The Hungarian Archaeology Database. *Internet Archaeology*, 58. DOI: 10.11141/ia.58.9

Kreuz, A., 2007. Closed forest or open woodland as natural vegetation in the surroundings of Linearbandkeramik settlements? *Vegetation History and Archaeobotany*, 17(1), 51-64. DOI: 10.1007/s00334-007-0110-1

Kreuz, A., Pomázi, P. and Bánffy, E., 2020. Hungarian Neolithic landscapes, crops and diet – Signs of cultural decisions? *Quaternary International*, 560-561, 102-118. DOI: 10.1016/j.quaint.2020.06.008

Laabs, J. and Knitter, D., 2021. How Much Is Enough? First Steps to a Social Ecology of the Pergamon Microregion. *Land*, 10(5), 479. DOI: 10.3390/land10050479

Ladányi, Zs., Blanka, V., Meyer, B., Mezősi, G. and Rakonczai, J., 2015. Multi-indicator sensitivity analysis of climate change effects on landscapes in the Kiskunság National Park, Hungary. *Ecological Indicators*, 58, 8-20. DOI: 10.1016/j.ecolind.2015.05.024

Legendre, P. and Legendre, L., 2012. *Numerical ecology*. Developments in environmental modelling, 24. Amsterdam: Elsevier. Available from: https://www.sciencedirect.com/science/book/9780444538680

Mádl-Szőnyi, J., Tóth, J. and Pogácsás, Gy., 2008. Soil and wetland salinization in the framework of the Danube-Tisza Interfluve hydrogeologic type section. *Central European Geology*, 51(3), 203-217. DOI: 10.1556/CEuGeol.51.2008.3.3

Magyari, E.K., 2011. Late Quaternary Vegetation History in the Hortobágy steppe and middle Tisza floodplain, NE Hungary. *Studia Botanica Hungarica*, 42, 185-203.

Marcon, E., Traissac, S. and Lang, G., 2013. A Statistical Test for Ripley's K Function Rejection of Poisson Null Hypothesis. *ISRN Ecology*, 2013, 1-9. DOI: 10.1155/2013/753475

Michéli, E., Fuchs, M., Hegymegi, P. and Stefanovits, P., 2006. Classification of the Major Soils of Hungary and their Correlation with the World Reference Base for Soil Resources (WRB). *Agrokémia* és *Talajtan*, 55(1), 19-28. DOI: 10.1556/Agrokem.55.2006.1.3

Milisauskas, S. and Kruk, J., 2011. Middle Neolithic/Early Copper Age, Continuity, Diversity, and Greater Complexity, 5500/5000-3500 BC. *In:* Milisauskas, S., ed. *European Prehistory: Interdisciplinary Contributions to Archaeology*, New York: Springer.

Moskal-del Hoyo, M., Lityńska-Zając, M., Raczky, P., Anders, A. and Magyari, E.K., 2018. The character of the Atlantic oak woods of the Great Hungarian Plain. *Quaternary International*, 463, 337-351. DOI: 10.1016/j.quaint.2017.02.029

Nakoinz, O., 2019. *Zentralität. Theorie, Methoden und Fallbeispiele zur Analyse zentraler Orte*.

Nakoinz, O. and Knitter, D., 2016. *Modelling Human Behaviour in Landscapes: Basic Concepts and Modelling Elements*. (Quantitative Archaeology and Archaeological Modelling). Cham: Springer International Publishing.

Nyári, D., Kiss, T. and Sipos, Gy., 2007. Investigation of Holocene blown-sand movement based on archaeological findings and OSL dating, Danube-Tisza Interfluve, Hungary. *Journal of Maps*, 3(1), 46-57. DOI: 10.1080/jom.2007.9711028

Orton, C.R., 1982. Stochastic process and archaeological mechanism in spatial analysis. *Journal of Archaeological Science*, 9(1), 1-23. DOI: 10.1016/0305-4403(82)90002-4

Panagos, P., van Liedekerke, M., Jones, A. and Montanarella, L., 2012. European Soil Data Centre: Response to European policy support and public data requirements. *Land Use Policy*, 29(2), 329-338. DOI: 10.1016/j.landusepol.2011.07.003

Parkinson, W.A., 2002. Integration, Interaction, and Tribal 'Cycling': The transition to the Copper Age on the Great Hungarian Plain. *In:* Parkinson, W.A., ed. *The Archaeology of Tribal Societies*, New York: Berghahn Books Incorporated, 391-438.

Pebesma, E., 2018. Simple Features for R: Standardized Support for Spatial Vector Data. The R Journal 10:1, 439-446. DOI: 10.32614/RJ-2018-009

Pebesma, E. and Bivand, R., 2005. S Classes and Methods for Spatial Data: the sp Package.

Pebesma, E., 2022. *stars: Spatiotemporal Arrays, Raster and Vector Data Cubes* (Version R-package version 0.5-6). Available from: https://r-spatial.github.io/stars/, https://github.com/r-spatial/stars

Raczky, P., 1989. Chronological framework of the Early and Middle Neolithic in the Tisza region. *Varia Archaeologica Hungarica*, 2, 233-251.

Raczky, P., 1995. Neolithic settlement patterns in the Tisza Region of Hungary. *In:* Aspes, A., ed. *Settlement patterns between the Alps and the Black Sea 5th to 2nd Millennium B.C.: symposium. Modelli insediativi tra Alpi e Mar Nero dal 5° al 2° millennio A.C. : atti del simposio internazionale, Verona 1991.* (Memorie del Museo Civico di Storia Naturale di Verona, 2a Serie, Sezione Scienze dell'Uomo, n. 4.). Milano: Università degli Studi; Verona: Museo Civico di Storia Naturale, 77-86.

Raczky, P. and Anders, A., 2009. Settlement history of the Middle Neolithic in the Polgár micro-region (The development of the Alföld Linearband Pottery in the Upper Tisza Region, Hungary). *In:* Kozłowski, J.K., ed. *Interactions between*

different models of neolithization north of the central European agro-ecological barrier: papers presented on the symposium organized by the EU project FEPRE (The Formation of Europe: Prehistoric Population Dynamics and the Roots of Socio-Cultural Diversity) [Interakcje pomiędzy różnymi modelami neolityzacji na północ od środkowoeuropejskiej *granicy agro-ekologicznej].* (Prace Komisji Prehistorii Karpat, 5). Kraków: Polska Akademia Umiejętności, 31-50.

Raczky, P., Sümegi, P., Bartosiewicz, L., Gál, E., Kaczanowska, M., Kozłowski, J. K. and Anders, A., 2010. Ecological barrier versus mental marginal zone? Problems of the northernmost Körös culture settlements in the Great Hungarian Plain. *In:* Gronenborn, D. and Petrasch, J., eds. *Die Neolithisierung Mitteleuropas. 2 vols: Internationale Tagung, Mainz 24. bis 26. Juni 2005. The Spread of the Neolithic to central Europe: International Symposium, Mainz 24 June-26 June 2005.* Regensburg: Schnell & Steiner GmbH, 147-173.

Sherratt, A., 1981. Plough and pastoralism: aspects of the secondary products revolution. *In:* Hodder, I., Isaacs, G. and Hammond, N., eds. *Pattern of the past: Studies in honour of David Clarke.* Cambridge: Cambridge University Press, 261-305.

Sielmann, B., 1972. Die frühneolithische Besiedlung Mitteleuropas. *In:* Schwabedissen, H., ed. *Die Anfänge des Neolithikums vom Orient bis Nordeuropa Westliches Mitteleuropa.* Köln: Böhlau, 1-65.

Sümegi, P., 2004. Environmental changes under the neolithization process in central Europe: before and after. *Anthaeus*, 27, 117-128.

Sümegi, P., 2008. Paleogeographical background of the Mesolithic, Early Neolithic settlements in the Carpathian Basin. *In: Proceedings of the 15th UISPP Congress,* Lisboa, 47-51.

Szécsényi-Nagy, A., Brandt, G., Keerl, V.; Jakucs, J., Haak, W., Möller-Rieker, A., Köhler, K., Mende, B. G., Fecher, M. Oross, K., Marton, T., Osztás, A., Kiss, V., Pálfi, Gy., Molnár, E., Sebők, K., Czene, A., Paluch, T., Šlaus, M., Novak, M., Pećina-Šlaus, N., Ősz, B., Voicsek, V., Somogyi, K., Tóth, G., Kromer, B., Bánffy, E. and Alt, K. W., 2014. Tracing the genetic origin of Europe's first farmers reveals insights into their social organization. *BioRxiv*, 8664. DOI: 10.1101/008664

Timár, G., Sümegi, P. and Horváth, F., 2005. Late Quaternary dynamics of the Tisza River: Evidence of climatic and tectonic controls. *Tectonophysics*, 410(1-4), 97-110. DOI: 10.1016/j.tecto.2005.06.010

Vanacker, V., Govers, G., van Peer, P., Verbeek, C., Desmet, J. and Reyniers, J., 2001. Using Monte Carlo Simulation for the Environmental Analysis of Small Archaeologic Datasets, with the Mesolithic in Northeast Belgium as a case study. *Journal of Archaeological Science*, 28(6), 661-669. DOI: 10.1006/jasc.2001.0654

Whittle, A.W.R., ed., 2007. *The Early Neolithic on the Great Hungarian Plain: investigations of the Körös culture site of Ecsegfalva 23, County Békés*. (Varia Archaeologica Hungarica 21. Budapest: Archaeological Institute of the Hungarian Academy of Sciences.

Wickham, H., François, R., Henry, L. and Müller, K., 2022. *dplyr: A Grammar of Data Manipulation* (Version R package version 1.0.8). Available from: https://cran.r-project.org/package=dplyr

Wiegand, T. and Moloney, K.A., 2004. Rings, circles, and null-models for point pattern analysis in ecology. *Oikos*, 104(2), 209-229. DOI: 10.1111/j.0030-1299.2004.12497.x

Wiegand, T. and Moloney, K.A., 2013. *Handbook of Spatial point-pattern analysis in Ecology.* New York: Chapman and Hall and CRC.

Wollák, K. and Raczky, P., 2012. Large-scale preventive excavations in Hungary. *In:* Bofinger, J. and Krausse, D., eds. *Large-scale excavations in Europe: Fieldwork strategies and scientific outcome: Proceedings of the International Conference Esslingen am Neckar, Germany, 7th-8th October 2008.* (EAC occasional paper, 6). Brussel: Europae Archaeologiae Consilium (EAC), 115-136.

Data and code availability

Supplementary data and code to replicate the results using individual datasets can be accessed using this link: https://zenodo.org/record/7307543 [Accessed, 3 Feb 2023]

DEM: German Aerospace Center (DLR) (2018):

TanDEM-X – Digital Elevation Model (DEM) – Global, 90m. DOI:10.15489/ju28hc7pui09, https://download.geoservice.dlr.de/TDM90/ [Accessed 16 Feb 2022]

SOIL: European Soil Data Centre (ESDAC), https://esdac.jrc.ec.europa.eu/ [Accessed, 16 Feb 2022]

HYDRO: European Catchments and Rivers Network System (Ecrins)

https://www.eea.europa.eu/data-and-maps/data/european-catchments-and-rivers-network [Accessed 16 Feb 2022]

OpenStreetMap contributors (2022): *Planet dump retrieved from http://download.geofabrik.de/*, http://download.geofabrik.de/ [Accessed 9 Mar 2022]

The possible effect of plant cover on wind comfort in the Late Neolithic: A case study using environmental reconstruction for the site of Makaranda (northern Serbia)

Aleksandar Medović, Robert Hofmann, Martin Furholt, Tijana Stanković Pešterac, Ildiko Medović, Stefan Dreibrodt, Liudmyla Shatilo, Kata Furholt, Fynn Wilkes, Darko Radmanović, Nikola Mrkšić

Abstract

Past human communities interacted extensively with the environment. They developed strategies that included natural resources and human-made structures to protect themselves from the natural elements. Can evidence of the existence of natural forces in the past be useful when reconstructing the natural environment of settlements? The Late Neolithic site of Makaranda is situated in the south-eastern part of the Pannonian Plain, in northern Serbia. Today, a strong, cold, SE wind, known as the Koshava, prevails in the region during autumn and winter. According to recent studies, it also prevailed during the early Holocene. If they had been left unprotected, the north-east – south-west orientation would have fully exposed the five houses found at Makaranda to stormy gusts. There are several possibilities for protecting a house from stormy or cold winds: shelter-providing natural or human-made obstacles or thick house walls. Trees and shrubs are effective windbreaks on the plain. The results of our research indicate the existence of extensive oak – elm forests in the vicinity of the site during the Late Neolithic. A deciduous forest windbreak would not stop the wind; it would only reduce it, and in winter, due to the deciduous trees' lack of leaf mass, the impact of such a windbreak on wind speed would have been significantly reduced. The remains of thick wattle-and-daub walls that have been discovered at the site indicate the possibility of the occupants using a dual strategy to increase the energy efficiency of Neolithic houses.

Using a combination of palaeoclimatological, geomagnetic, macro-botanical, botanical, anthracological, palynological, geomorphological, malacological and climatic proxy evidence preserved at three Neolithic sites on the Borđoš Late Pleistocene Terrace (Prečka, Borđoš and Makaranda) and one pollen core (from the vicinity of Makaranda), we propose a circumstantial reconstruction of the natural environment of the site.

Keywords: *prevailing winds, vegetation, house orientation, Late Neolithic, Borđoš, northern Serbia, Pannonian Plain*

If there was no wind, spiders would cover the sky in their webs
(Serbian proverb)

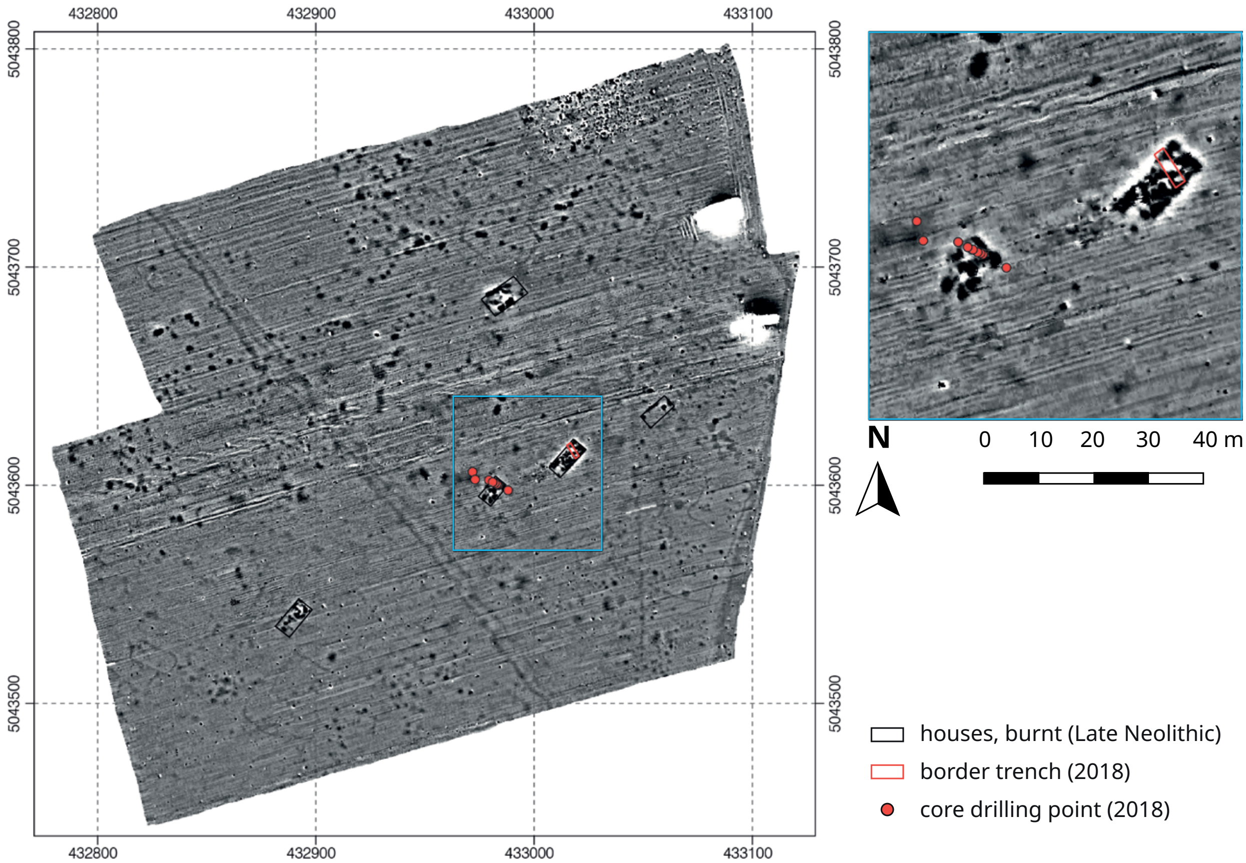
Introduction

Today, northern Serbia is characterised by a strong, cold SE wind (Fig. 1), especially during autumn and winter, and the inhabitants of flats with southern and eastern exposure in the region's main town of Novi Sad stuff the cracks around their windows with newspapers to prevent the cold from entering their living space. The fact that the five houses at the Late Neolithic site of Makaranda have a NE – SW orientation and that their long (SE or NW) sides were left fully exposed prompted us to ask the following questions: Did this cold, SE wind, known as the Koshava, also blow in prehistory? And if it did, how did people protect their houses from it, and is there any evidence for protection measures reflected in the vegetation that surrounded the site and the individual houses (Figs. 2 and 3)?

Study area

The northern part of Serbia is in the south-eastern part of the Carpathian (also known as Pannonian) Basin. The province of Vojvodina, while mostly flat, contains two mountainous zones (Fig. 4): Vršačke Planine (641 m above mean sea

*Figure 1. A weeping willow tree (*Salix babylonica *L.) toppled by a strong gust of wind from the SE, on the quay at Novi Sad (province of Vojvodina, Serbia), which is located at the edge of the core Koshava wind zone, on November 26, 2021, shortly after 8 a.m. (photo: Radio 021).*



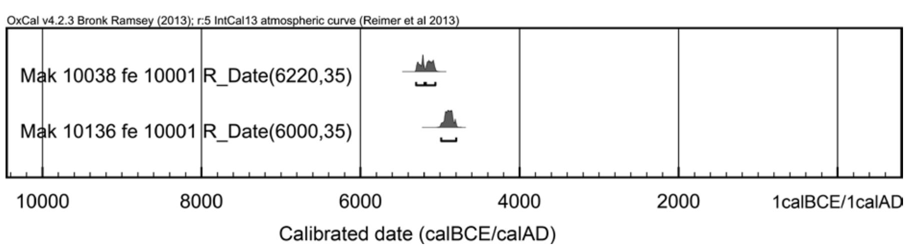


Figure 2 (above). Survey magnetogram of the Late Neolithic site of Makaranda (province of Vojvodina, Serbia).

Figure 3 (left). ^{14}C dating of two samples taken from the Tisza culture house at the Late Neolithic site of Makaranda (province of Vojvodina, Serbia).

level (AMSL)) in the south-east (Sipos *et al.* 2022) and Fruška Gora (539 m AMSL) in the south-west. Other significant geomorphological features include two areas of sandy terrain, Deliblato Sands (250 m AMSL) in the south-east and Bačka Sands (134 m AMSL) in the north, as well as six large loess plateaus (Marković *et al.* 2008). The region is characterised by spatially elevated, stepped surfaces – loess plateaus, sands, Late Pleistocene terraces, and the alluvial plains of the Danube and Tisza rivers and their tributaries.

Forests comprise only about 7% of the investigated region and mainly occur in the mountains and parts of the sandy terrain along the banks of the Danube, Sava, and Tisza rivers and their main tributaries, while agricultural land occupies about 83% (Pokr. skupšt. odl. progr. zašt. život. sred. Auton. pokr. Vojv. period 2016-2025. god. 2016).

The climate of northern Serbia is moderately continental, with cold winters and hot summers. The average annual air temperature is 11.1 °C, and the average annual precipitation is 606 mm (Tošić *et al.* 2014). According to the De Martonne aridity index, northern Serbia has a semi-humid climate (Hrnjak *et al.* 2014).

The low relief and general lack of forest cover provide few obstacles to the wind, *i.e.* the boundary layer is thin and surface friction is low. The landscape of Vojvodina corresponds to European landscape of Type 1 (Troen and

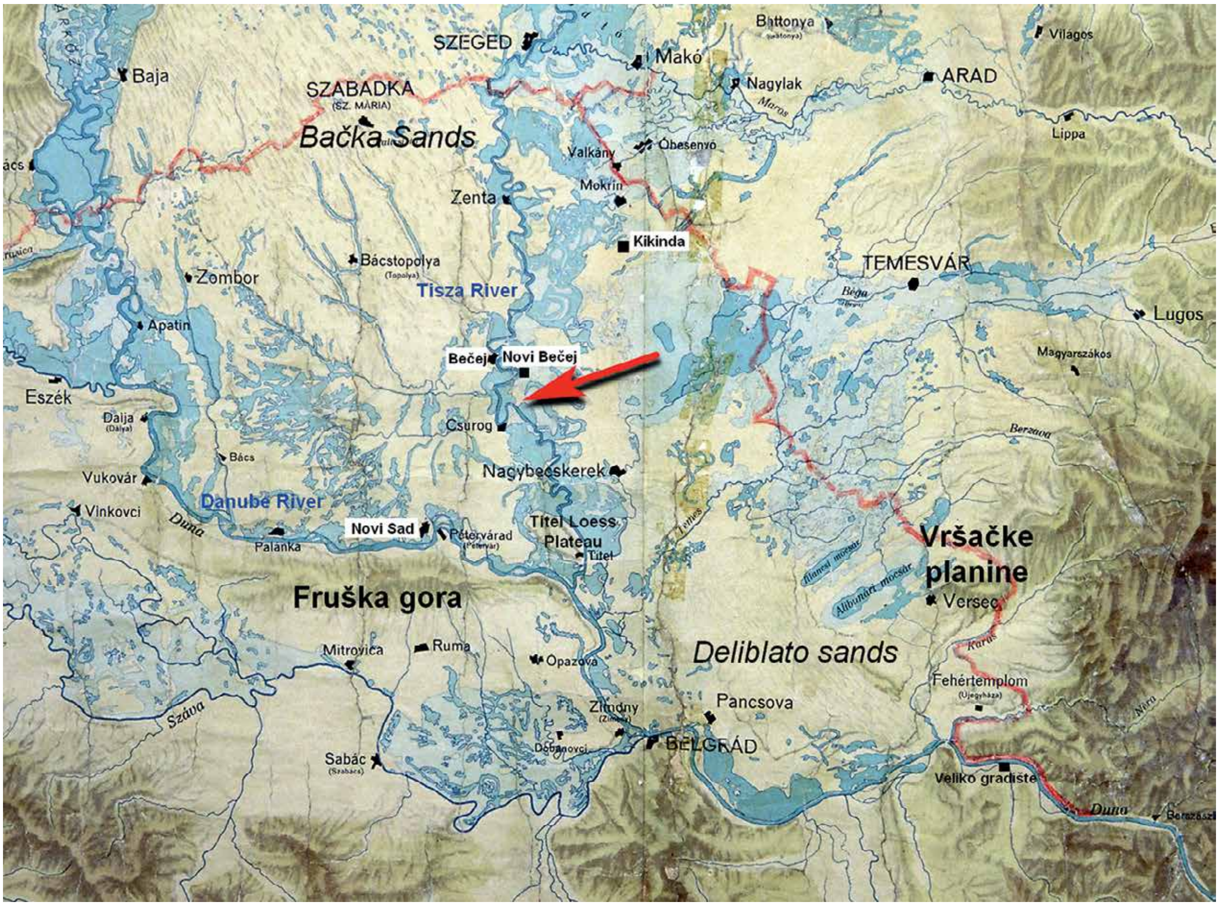


Figure 4. Map of the province of Vojvodina (Serbia) before amelioration of the rivers in the late nineteenth century, showing its geomorphological characteristics and the location of the Borđoš Late Pleistocene Terrace (arrow).

Petersen 1989), *e.g.* plains, water areas, and lowland regions far from mountains. Winds near surface can only be modified by changes in the roughness of the land surface and by sheltering obstacles.

The prevailing surface winds in the region

The prevailing surface winds in the region during the early Holocene

Studies of modern wind measurements and geomorphological data suggest that two wind directions predominate in northern Serbia: SE winds, in the Deliblato Sands, in the southern Banat subregion, for all palaeo (the early Holocene, the latest last glacial period, and the LGM) and modern intervals, and NW winds, over the rest of northern Serbia in the recent and last glacial periods. The SE winds were probably responsible for the formation of dunes in the Deliblato Sands and perhaps for much of the loess in northern Serbia (Marković *et al.* 2008; Gavrilov *et al.* 2018).

The prevailing surface winds in the region today

The prevailing surface winds in northern Serbia today come from SE and NW direction (Tošić *et al.* 2018), with a frequency of ca. 116 and 105 days/year, respectively; those within Deliblato Sands come with a frequency of 115 and 129 days/year, respectively (Gavrilov *et al.* 2018).

Generally, surface winds can be significantly modified or influenced by terrain orography, surface composition, thermal conditions, and plant cover. Northern Serbia is mostly flat, the obstacles for the airflow are minimal, the boundary layer is very thin, and surface friction is very low, and all these factors minimally modify the local winds. In northern Serbia, NW and SE winds prevail in spring, NW winds prevail in summer, and SE winds prevail in autumn and winter. The primary cause of wind over northern Serbia is the synoptic situation. For the NW wind, the synoptic situation is characterised by depression over north-eastern Europe, with high pressure over the Azores. For the SE wind, it is characterised by high pressure over eastern Europe and low pressure in the central or western Mediterranean. The Koshava wind occurs in a relatively small area in the south-eastern Carpathian Basin. Its core zone extends from Novi Sad in the west, to Veliko Gradište in the east, Bečej in the north-west, and Kikinda in the north (Fig. 4) (Gavrilov *et al.* 2018) and has long been identified as the windiest part of Serbia, with the annual wind energy density surpassing 2700 kWh/m^2 (Gburčik *et al.* 2013). The site of Makaranda is situated on the northern edge of the Koshava core area.

The Koshava wind

The Koshava is a local wind usually present in the cold part of the year (Tošić *et al.* 2018) over a large part of Serbia, parts of Romania, parts of Hungary, and eastern Croatia (Romanić 2016). It starts in the Carpathian Mountains and follows the River Danube north-west through the Iron Gates region, where it gains a jet effect, then continues to the south-eastern Pannonian Plain. The Koshava is also known as the Banat wind (referring to the fact that it blows in the Banat subregion) (Gavrilov *et al.* 2018). The Serbian name for the wind, Koshava, has a 17th-century Turkish origin, from koç hava, meaning 'fast air' (the Turkish Empire ruled the western Balkan region at that time) (Skok 1972; Romanić *et al.* 2015). The main characteristics of this wind are its high wind speed, SE direction, persistence and gustiness (Romanić 2016). In winter, a strong subjective feeling of cold is attached to it because of its speed. The strongest Koshava gust ever recorded was measured at Vršac, on 11 February 1987 (48 ms-1 at 10 m above ground=172.8 km/h) (Romanić *et al.* 2016). It is a persistent wind that usually blows for 2-4 days at a time but can be active for as long as 18-22 consecutive days (Romanić *et al.* 2015). On average, the Koshava is active 32.4% of the year. Koshava winds persisting for longer than 5 days are most frequent in November and December, *i.e.* at the end of autumn and the beginning of winter (Unkašević *et al.* 2007). However, the strongest Koshava winds occur in March and January (Romanić 2016), during the leafless period (see also Fig. 8). Generally, wind speeds tend to increase from the early morning (7 a.m.) to the afternoon (2 p.m.) (Romanić 2016). The afternoon Koshava winds have higher absolute speed values than the morning ones (Romanić *et al.* 2015).

Statistically significant decline in Koshava wind speeds and wind activity were observed for the period 1949-2010, and these trends were more pronounced for wind speeds above 5ms-1. The negative trends are mostly related to the changes in large-scale weather patterns (Romanić *et al.* 2015). The observed decline in the Koshava wind has a significant impact on reducing the wind energy potential in the region (Romanić *et al.* 2015). It seems that the construction of the hydropower dam and reservoir system Iron Gates I and II, built in 1970, and the rise of the water level of 2.5-19.7 m (Drapa and Balaet 2009) had no significant effect on wind speed. Before the construction of the dam system, the bed of the River Danube between Ram and Golubac looked completely different. It was a river full of rapids, whirlpools, and sandy beaches. Both banks were bordered

by willows and poplars. Blowing over the terrain, the Koshava loses its energy, and the wind potential is decreasing from the south-east to the north-west of Vojvodina (Đurišić *et al.* 2007).

Natural windbreaks

Most natural windbreaks are porous objects. Vegetation, in general, decreases wind velocity. Wind speed is a function of barrier height, porosity, distance from the barrier, height above the surface, roughness length in the uninterrupted wind, and atmospheric stability (Forman 1995). The windbreak height determines the extent of the protected zone.

The quiet zone is located just behind the barrier. Its length is generally about eight heights of the windbreak. The zone is characterised by lower horizontal wind speed and higher turbulence than occurs in airflow in the open. From about 8 to about 30 heights (hereinafter: h) of windbreak or more is the wake zone, characterised by higher wind speed, greater turbulence, and larger 'eddy' sizes (small, circular flows within turbulence) than in the quiet zone. Wind patterns in the wake zone gradually change downwind, until they merge with those in the open. Wind speed reductions of about 20% commonly extend some 25h downwind of vegetation windbreaks (Forman 1995). A windbreak of deciduous trees during the leafless period typically exhibits at least 50% of the wind reduction that it possesses during the foliage period (Forman 1995).

Downwind of a forest, wind patterns appear similar to those behind an impenetrable windbreak, in that high turbulence and a relatively short area of reduced wind speed are present. This is probably largely due to the low porosity of a forest. However, turbulence produced by a rough forest-canopy surface, such as an old-growth forest or tropical rainforest, will further decrease the downwind distance of the wind speed reduction (Forman 1995).

Gaps in perpendicular windbreaks (where gap width is <h) often have wind speed increases of 20% or more. Horizontally flowing air is 'squeezed' into the gap, causing an acceleration in a hot or insect-infested place that would feel good. In a cold, windy location it would feel frigid (Forman 1995).

Effects on microclimate, soil, snow, plants and cattle

Windbreaks reduce soil erosion, catch and hold snow, provide soil moisture in steppe areas, protect crops from desiccation, protect livestock and reduce home energy costs (Forman 1995). By protecting them against extreme winds, cattle are made more thermally comfortable, allowing energy to be used for maintenance and milk production (Sturrock 1981). Windbreaks can improve water use efficiency through reduced evapotranspiration; the air around the soil and plant becomes more humid, and this slows the process of evapotranspiration down.

Air temperature is higher in the quiet zone and lower in the wake zone compared with conditions in the open (Forman 1995). The maximum temperature appears to be in the quiet zone, at about 4h downwind. Atmospheric humidity appears to increase in the quiet zone and decrease in the wake zone. Overall, windbreaks modify wind speed and evaporation much farther downwind than they affect other microclimatic conditions.

Soil moisture, day air temperature, day soil temperature, and relative humidity increase, while night air temperature, evaporation and wind speed decrease downwind of a windbreak (Forman 1995).

Natural windbreaks, such as trees, are very efficient barriers to high-velocity winds (Bitog *et al.* 2011). The windbreaks exert drag force, causing a net loss of

momentum and thus disturbing the characteristics of flow. The main factors that can affect the efficiency of the tree windbreaks are tree height, width, arrangement and porosity. However, tree porosity, which is strongly related to windbreak drag, is very difficult to establish. The reduction in wind speed behind a windbreak modifies the environmental conditions or microclimate in the sheltered zone (Bitog *et al.* 2011). Maximum wind reductions are closely related to porosity, with low porosity producing a high maximum reduction (Heisler and Dewalle 1988). Barriers with very low porosity create more turbulence downwind than do medium-porosity barriers. The higher turbulence may result in the recovery of mean horizontal wind speeds to upwind speeds closer to low-porosity barriers, thus resulting in a shorter protected distance. For providing significant (10-30%) reductions in mean wind speed near the ground for the largest distance, solid or very dense barriers are less effective than medium-porous barriers (Heisler and Dewalle 1988). Height growth would usually be a more important criterion than density when selecting between species to protect a large area of ground. High density would be the first consideration when large reductions over a short distance are needed.

As a general rule, porosity is approximately 0.5 for trees (Troen and Petersen 1989). The porosity of trees changes with foliation. Therefore, in wintertime, the porosity of trees is much higher than during the vegetation period. This impacts the wind porosity of the sheltering obstacles and, therefore, the wind speed near the ground. In terms of wind velocity reduction, several simulation studies have shown that the optimal value for porosity ranges between 20% and 35% (Bitog *et al.* 2011). Unfortunately, the porosity of trees is very complex to deal with and very difficult to determine. In the south-eastern part of the Czech Republic, wind field measurements were carried out on a windbreak of poplar. In April, the reduction in average wind speed as a result of the windbreak was approximately 17%, while in October it was about 37% (Středa *et al.* 2014). Dependence on the main species' foliage stage, the effect of the windbreak was obvious on the leeward side to a distance of 100-150 m (*c.* 5-7h) (Středa *et al.* 2014). The maximum effective wind-preventing range of a poplar forest is about 150 m.

According to recent six-year-long phenological observations in an area of Vojvodina near the River Danube (the village of Deronje, 85 m AMSL, at almost the same latitude as Makaranda), the start of the leaf-unfolding phase of the pedunculate oak is between March 25 and April 20 and the end is between April 12 and April 28 (Pekeč *et al.* 2017). The start of the leaf-fall phase of the pedunculate oak is between October 31 and November 25. The end of the leaf-fall phase is between November 25 and December 5. It is noticeable that the leaf-unfolding and leaf-fall phases varied depending on the year of observation. The main drivers of these phenophases are climatic factors, *i.e.* solar radiation, humidity and air temperature, which affect the initiation of physiological processes in plants and result in the processes of leaf unfolding or leaf fall. This means that during the coldest part of the year, lasting between four to five months, trees are the most porous to the wind.

Vegetation can not only decrease the wind velocity but accelerate it (Szkordilisz and Zöld 2016). Trees can redirect airflow downward, while shrubs can do so upward. The combined effect of low air temperature and wind velocity (known as wind-chill) may result in thermal discomfort. The canopy of trees hinders the airflow from about 3 m above ground; therefore different combinations of shrubs and trees may prevent wind discomfort.

For humans, the purely mechanical effects of wind are a disturbance of clothing and hair, resistance during walking, and buffeting of the body and carried objects (*e.g.* umbrellas). Accompanying effects are the of blowing grit and dust and lifting of loose papers these unpleasant phenomena start at about 5 m/s wind velocity. A mean velocity of 15 m/s is considered a threshold of danger; at this mean velocity people may lose their balance. Note that the mean includes gusts (Szkordilisz and

Zöld 2016). A horizontal wind equal to or exceeding the terminal velocity will cause a particle to descend at an angle of 45° or less to the horizontal. For fine drizzle, 1 m/s can already lead to this situation, and even for large drops, 7 m/s is enough. Driving rain and particles may irritate the eyes and skin, as in addition to the clothed surfaces of the body, some bare parts are also exposed to these effects.

Reconstructing the vegetation surroundings of the Late Neolithic site of Makaranada

Potential natural vegetation in the region

According to the Map of the Natural Vegetation of Europe (Bohn and Neuhäusl 2000) the north-western subregion of Banat is a forest-steppe region, *e.g.* a sub-Mediterranean – subcontinental lowland to montane herb-grass steppes, partly meadow steppes (*Festuca valesiaca* Schleich. ex Gaudin, *Stipa* spp., *Bothriochloa ischaemum* (L.) Keng, *Chrysopogon gryllus* (L.) Trin.) alternating with oak forests (*Quercus pubescens* Willd., *Q. robur* L., *Q. pedunculiflora* K. Koch) also containing *Acer tataricum* L.

The terms forest-steppe and steppe forest are interpreted differently (Gams 1986). A steppe forest is a light forest with steppe vegetation beneath trees and in forest clearings, whereas a forest steppe is a mosaic of sharply separated forest and grass-steppe surfaces. According to Horvat and colleagues (1974), a landscape is designated as a steppe forest region if the more significant part of it is naturally stocked with open forest. The authors assume that the potential natural vegetation for these sites far from groundwater consists mainly of xerothermic mixed oak forests. These forests were never fully closed, reflecting dry growing season conditions, combined with other natural factors, such as storms, wildfires, insect infestations, and anthropogenic and herbivore impacts, that favoured grassland persistence throughout the Holocene (Magyari *et al.* 2010; Goderie 2013; Feurdean *et al.* 2015). According to Parabućski and Janković (1978), the climate of Vojvodina is not steppic. They believe that without anthropogenic factors, today' meadow steppes would develop into steppes and would successfully turn into a forest of the type *Aceri tatarici-Quercion* Zolyomi et Jakucs, 1957.

Hardwood alluvial forests, in combination with willow and poplar alluvial and wet lowland, grow in the large river valleys of the Carpathian Basin (Bohn and Neuhäusl 2000). Arms of the river and canals intersect specific complexes of alluvial forests, islands, meanders, occasional brooks called wok, ponds with muddy bottoms called *tonja*, ponds, swamps, wet meadows, reeds and woodlands.

The impact of humans and domesticated animals is very influential in changing the landscape and hence constantly altering the vegetation. Reconstructions of the environment in prehistoric times often lack mention of other factors, such as keystone species (a species on which other species in an ecosystem largely depend) such that if it were removed, the ecosystem would change drastically, *e.g.* aurochs (*Bos primigenius* Bojanus).

Palaeoclimatology

During the Late Pleistocene, the climatic conditions were marked by a slow increase in temperature, with an interruption during the Late Glacial (Younger Dryas: 11000-9700 BCE). Nonetheless, average summer temperatures were still around 6°C cooler than today (Magyari 2011). During this time, the presence of tree pollen in pollen diagrams increases in most parts of Europe (Binney *et al.* 2017). The dominant form of

vegetation in the Carpathian-Pannonian area was the grass steppe, except in the alluvial plains, where trees were more common (Magyari *et al.* 2014).

The early Holocene Preboreal is marked by a wet and cool phase 9600-8200 BCE and by the shift from cold grass-steppe vegetation to a temperate, wooded steppe (Nádor *et al.* 2007; Schumacher *et al.* 2016). With the growing density of forests during this first phase of the Holocene, the water inflow into the rivers decreased and discharges became smaller (Charlton 2010).

Conditions changed again during the Boreal (8200-6000 BCE), and a warmer and drier phase occurred. While temperate forests and wetland meadows persisted in the alluvial plains, cool forest steppes were the main vegetation type on the surrounding terraces (Magyari *et al.* 2010).

The beginning of the Atlantic (6000-3000 BCE) was warmer, and conditions became wetter. By the end of the Atlantic, however, climatic conditions became warm and dry. Human impact is traceable in the pollen record of this period and increases over time (Magyari *et al.* 2010).

Vegetation of the early Holocene in the region

The development of the unique vegetation mosaic during the early Holocene, extremely rich in species, was controlled not only by the climate system of the Carpathian Basin, but also by regional and local edaphic factors (orography, bedrock geology, hydrology, soils) (Sümegi *et al.* 2013).

Recent scientific studies indicate that temperate deciduous wooded steppe persisted in the Great Hungarian Plain throughout the Holocene and that the early Holocene period witnessed greater vegetation openness between 11 400 and 9900 cal. yr bp. (Magyari *et al.* 2010). Analyses of the environmental transformations in the Carpathian Basin at the end of the Late Glacial and Early Holocene (*e.g.* Magyari *et al.* 2012; Feurdean *et al.* 2014) have mainly focused on the plant and animal remains in temperate wetlands (Sümegi *et al.* 2022). Dryland environmental transformations in response to Late Glacial and Early Holocene climate change of the loess areas of the Carpathian Basin have not yet been modelled. Based on the bioclimatic models (Szelepcsényi *et al.* 2014, 2018), a decrease in humidity that limited the spread of trees in the Carpathian Basin caused the development of this unusually wide ecotone, the Pannonian forest-steppe region. Therefore, the emergence of transitional zones between woodlands and grasslands would generally have been controlled by the availability of humidity as a limiting factor (Szelepcsényi *et al.* 2014, 2018).

Present-day vegetation in the wider surroundings of Makaranda

Recent botanical research conducted at the Titel Loess Plateau can significantly contribute to a better understanding of the vegetation development on the loess areas in Vojvodina through time (Butorac *et al.* 2008). The Titel Loess Plateau is situated between the rivers Danube and Tisza, close to the confluence (Fig. 4). It is a loess 'island' that rises above the plains of the south-eastern part of the province of Bačka, in northern Serbia. The vegetation of the loess plateau originally had all the climazonal characteristics of the mosaic complex of forest-steppe communities (Butorac *et al.* 2008). The latest research on the Titel Loess Plateau indicates that xerothermic forests are present in fragments on inaccessible terrains on its flank by the River Tisza (Butorac *et al.* 2008). Forest vegetation extends within a 100 m wide and 2-3 km long zone next to the River Tisza, covering the steep, inaccessible north-east slopes, the edges of clefts, and recesses. The vegetation includes elements of xerophilic and thermophilic forests, as well as some intermediate elements. This is a consequence of the accumulation of atmospheric sediments on the terraced

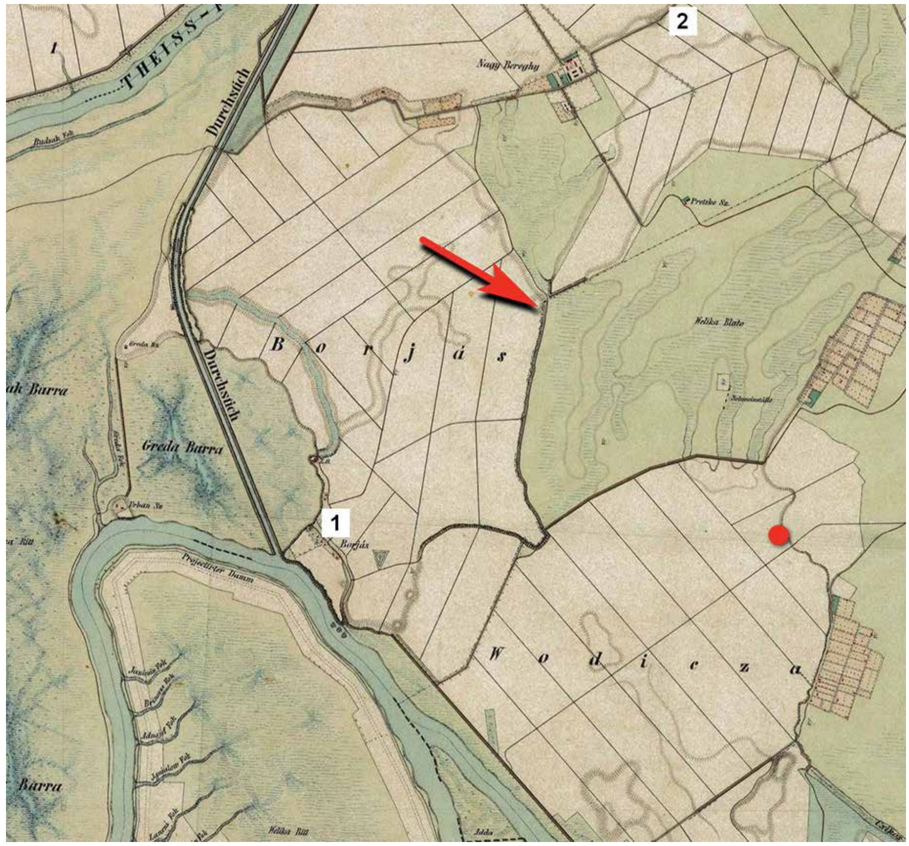


Figure 5. Map of the Borđoš Late Pleistocene Terrace (province of Vojvodina, northern Serbia) showing the location of Makaranda (arrow) and the two other Neolithic sites and the drilling core (dot) mentioned in the text. 1 Borđoš; 2 Prečka (the map was modified after © Österreichisches Staatsarchiv [Second military survey of the Habsburg Empire (1819-1869), Hungary [B IX a 1124]]).

geomorphologic forms and the action of water, which deepens the existing trenches and ravines, denuding the geological substratum.

Stands referred to as the association *Orno-Cotino-Quercetum pubescentis* Ass. nova prov. (Butorac *et al.* 2008) have forest features. Despite the noticeable presence of short trees and bushes and a very bushy herbaceous stratum, the main features are given by *Quercus pubescens* Wild., *Fraxinus ornus* L., *Ulmus carpinifolia* Gled., *Tilia tomentosa* Moench and other woody plants. The floristically poor stands of the sub-association named *Aceretosum tatarici* Subass. nova are linked with forwarding positions, crests of the plateau, the tops of slopes, and marginal positions exposed to wind and insolation. The stands have a more xerothermic character and grow under conditions of higher evaporation and lower humidity (Butorac *et al.* 2008). Forest stands are registered on the north-east slopes only, while shrubbery can be found throughout the area and on all exposures of the Titel Loess Plateau.

The water of the River Tisza has both negative and positive influences on the extent of forest stands on the Titel Loess Plateau. Although the river permanently erodes the plateau, creating a new rockslide, at the same time, evaporation from the river makes the macroclimate milder.

Macro-botanical and anthracological analyses of Makaranda, Borđoš and Prečka

Analyses on macro-botanical and anthracological remains from Makaranda reflect the presence of mixed vegetation and evidence of forest (*Quercus*, *Cornus mas* L.), marshes (*Alisma plantago-aquatica* L.), and steppe (*Stipa*) in the vicinity. Depending on the species, *Quercus* finds belong to floodplain forest (cf. *Q. robur*) or to oak-dominated wooded steppe on the Late Pleistocene Terrace (cf. *Q. pubescens*). The

existence of wood on the terrace on the higher topography, *e.g.* on the margins of the Late Pleistocene Terrace, is indicated by the finds of *Cornus mas*. At Prečka, among the charred wood, in addition to *Quercus* and *Ulmus*, we were also able to confirm the presence of willow/poplar (*Salix/Populus*) and sloe (*Prunus spinosa* L.).

The presence of forest on the Late Pleistocene Terrace is indicated by a buried, weakly developed cambic B-horizon at the sampling site of Borđoš. The presence of the steppe is also indicated by charred items of *Stipa* sp. (Hofmann, Medović *et al.* this volume) and by many krotovinas (filled-in animal burrows) in the investigated ditches.

Common water plantain (*Alisma plantago-aquatica*) is a semi-aquatic or aquatic plant that grows on swampy meadows; in ponds, ditches, ponds, lakes; and along the banks of slow-moving rivers (Grlić 1990; Lakušić *et al.* 2005). *Polygonum persicaria* L., of which charred items were found at Makaranda, is characteristic of plant communities that develop in oligotrophic, mesotrophic, and, rarely, eutrophic habitats where water is retained almost throughout the year. It is an adjunct species in the stratum of ground flora in oak – elm – ash lowland forests (Slavnić 1952).

Palynological analyses

Only one drilling core from the vicinity of the Late Pleistocene Terrace has been analysed for pollen, and only in part. The core was taken from a generation B meander (Popov *et al.* 2008) on the edge of a field, in 2018 (Wilkes 2019) (Fig. 5). The outcome of the preliminary results is rather unspecific, with the clearest signal being the vanishing of *Ulmus* pollen between the sample taken at 350 cm depth and that taken at 250 cm depth. This could indicate a decline in the proportion of elm trees between the Atlantic and Subboreal periods. However, these results are preliminary; for a more precise interpretation, the entire core must be analysed for pollen, sediment characteristics and dating (Wilkes 2019). Interestingly, pollen analyses could not confirm that ash (*Fraxinus*) was important in the forest, as would be expected. However, the results of the anthracological analyses could confirm that the main wood species in the vicinity were *Quercus* and *Ulmus*.

In general, one can presume the presence of closed woodland when the proportion of arboreal pollen is higher than 70% and the presence of forest-steppe-type vegetation when it is between 50% and 70% (Magyari *et al.* 2010; Sümegi *et al.* 2013). Disregarding the values for *Pinus* and *Corylus* pollen, the values are close to those needed for the assumption that we are dealing with forest-steppe-type vegetation in the vicinity of the Late Pleistocene Terrace.

The challenges of elm species identification

The wood of European white elm (*Ulmus laevis* Pall.) and field elm (*U. minor* Mill. (syn. *U. campestris* L.)) cannot be differentiated based on anatomical characteristics (Fig. 6) (Schweingruber 1990). However, in *U. laevis*, the distribution of the bands of pores in the latewood is more markedly tangential than in the other *Ulmus* species (Schweingruber 1990). Some species (*e.g. U. americana* L. and *U. laevis*) have continuous, single rows of earlywood vessels; others (*e.g. U. minor* et sim.) have multiple rows (Wheeler and Manchester 2007).

The European white elm is a hardwood deciduous tree that grows along river margins and in damp bottomland forests, tolerating flooding for some periods of the year (Collin *et al.* 2000). It can withstand more than 100 days of continual flooding. Although it is typically found in moist sites, it can also grow on moderately dry, deep soils. Its timber is of poor quality and thus of little practical use, not even as firewood (Caudullo and de Rigo 2016). Wood density is lower than in other elm species (Collin 2003).

Figure 6. Charred wood of elm (Ulmus) *from Trench 3 at the site Borđoš (province of Vojvodina, northern Serbia) (Hofmann, Medović et al. this volume) showing a distribution of the bands of pores in the latewood that is markedly tangential (cf.* U. laevis*) and multiple rows of earlywood vessels (cf.* U. minor *et sim.) (see text for details). Photo: A. Medović.*

Ulmus minor has an excellent ability to produce root suckers and to re-sprout from the stump (Collin *et al.* 2000). *U. minor* can rapidly colonise new sites by seed and then reproduce by root suckers, eventually forming thickets (Collin *et al.* 2000).

In the total forest inventory of the Serbia, autochthonous European white elm accounts for less than 1% (Banković and Ranković 2009). Both *U. minor* and *U. laevis* are considered rare and endangered species in Serbia.

During the Neolithic and the Bronze Age, elm was occasionally used for axe handles and posts (Schweingruber 1990).

The challenges of oak species identification

The wood of pedunculate oak (*Quercus robur*) and pubescent oak (*Q. pubescens*) cannot be differentiated based on anatomical characteristics (Schweingruber 1990).

Quercus robur grows in plains and valleys on deep, fertile, moist soil that occasionally floods. It also grows on soils that are not fertile on the surface but have enough nutrients and water in the deeper layers, but it does not thrive on dry and shallow soils. It can tolerate a certain amount of salt in the soil, while it does poorly on acidic soils. It is a photophilous species (Vrndžić 2020). It is characterised by a scattered treetop that allows a fair amount of light and the wind through.

About 5 km south of Makaranda, a single standing, ca. 300-year-old pedunculate oak represents a relic of an oak – elm forest (Fig. 7). It has been under protection since 1985 (Vrndžić 2020). It is 29.3 m high. The diameter of its treetop is 42 m. The trunk circumference measured at a height of 1.3 m is 7.5 m, while the diameter of the trunk is 2.4 m.

Quercus pubescens grows on shallow, underdeveloped and dry soil. Today, it is rare in the region. Recently, fragments of xerothermic woods of pubescent oak have been registered on the Titel Loess Plateau (Butorac *et al.* 2008).

The results of the macro-botanical and anthracological analyses, together with the results of other, multidisciplinary analyses from three sites, indicate the existence of two vegetation types in the vicinity of the Late Pleistocene Terrace (Hofmann, Medović *et al.* this volume): *Quercus* wooded steppes (*Q. pubescens* – *U. campestris*)

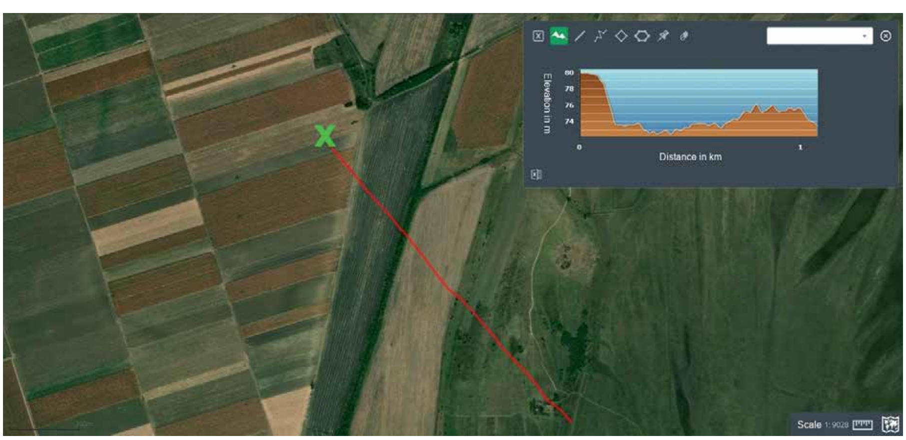


*Figure 7. A 300-year-old pedunculate oak (*Q. robur*) in the vicinity of the Borđoš Late Pleistocene Terrace (province of Vojvodina, northern Serbia) that is a relic of an oak – elm forest. Photo taken 8 April 2015.*

Figure 8. North-west – south-east profile of the Borđoš Late Pleistocene Terrace (province of Vojvodina, northern Serbia), showing the location of the house (×) that was excavated at Makaranda in 2018 (Vode Vojvodine 2019).

on the elevated surfaces and *Quercus* – *Ulmus (Q. robur* – *U. laevis)* forests in the seasonally flooded alluvium. The palynological data from the Great Hungarian Plain show that during the Atlantic period, the wooded steppe dominated in this region (Magyari *et al.* 2010). The open forest communities are characterised by a broken canopy, which allows a good development of heliophilous trees, such as *Cornus mas* and different species of *Prunus* growing in the shrub layers or at the forest edge (Moskal-del Hoyo and Lityńska-Zając 2016).

The impact of disappearing of lowland elm on climate change in the floodplain pedunculate forest

In the past century, the epidemic death of lowland elm in Croatia has caused significant changes in the climate of the ground layer in the floodplain of the pedunculate oak forest (Prpić 1974). The dying of the elms resulted in gaps and clearings in the forest, and at the same time, the underlying floor of the stand disappeared. Lowland elm is the only wood species in the floodplain pedunculate forest that tolerates shade and can form the underlying floor of the stand. With the disappearance of lowland elm in this forest, it became warmer and drier, and this change in phytoclimate caused very unfavourable conditions during both dry and wet periods. In the dry season, water reserves in the soil are reduced due to the abundance of heat and intensive evapotranspiration, and in wet periods there is overheating of the soil saturated with water and very unfavourable conditions in the rhizosphere. In both cases, there is a decrease in the vitality of pedunculate oak trees.

The impact of natural grazing on the natural surroundings

Vegetation in the vicinity of a settlement is a natural bridge linking water availability to plants, soil, climate and environmental factors, such as the effect of cattle grazing and manuring and the rate of landscape modification through human activities. The Carpathian Basin is very rich in species (ca. 3000 plant species and ca. 43 000 animal species), and it has colourful and varied ecological systems; thus, it is one of the areas with the richest vegetation in Europe (Mezősi 2017).

The ecological influence of wild animals, *e.g.* aurochs, on the vegetation in the past was significant. Aurochs can be considered a keystone species at Borđoš. The massive horn core of an aurochs bull was found at the bottom of the ditch next to one of the gates of what is termed the flat settlement of Borđoš. A keystone species helps define an entire ecosystem (Paine 1969). Only recently have scholars started to better understand the massive influence aurochs must once have had in the past. The aurochs dentition provides important clues to how it obtained food. It has hypsodont teeth, typical for grazers (which feed mainly on grasses) and not for browsers (which feed mainly on branches, bark and shoots). It therefore must have had a food selection very similar to the domestic cattle of today (Goderie 2013).

In nature, the number of natural grazing herbivorous mammals (*e.g.* aurochs, deer, horses, bison) is limited by the amount of food available during winter. (Goderie 2013). During that time, the animals need to search for alternative food sources, such as twigs, stems, and bark, and winter is therefore the period in which they have the strongest influence on trees and wooded vegetation, creating a mosaic pattern of open grasslands, thickets and woods. Pastures are grazed so intensively in summer that even thorny saplings will not survive. High livestock densities in summer with seasonal grazing lead to over-fertilising and over-trampling of soils and vegetation.

Human-made pastures are just variations of natural grasslands, the surrounding hedges are just variations of natural thickets, and the cattle themselves are just variations of the aurochs, and are trailblazers for several other herbivores, which have difficulties digesting long grass. Cattle and aurochs have kept the lands open for tens of thousands of years. Horning and rubbing by, *e.g.* bison (*Bison bison* L.), along with fire and drought, may have influenced the historical distribution of woody vegetation in prairie environments in Oklahoma, USA (Coppedge and Shaw 1997). Bison caused only minimal injury to trees but had a more significant effect on saplings and shrubs. Both aurochs and bison are capable of severely impacting woody vegetation.

In the drier areas, the bush overgrowth of open or sparsely wooded landscapes produces an immensely increased risk for large-scale, human-made forest fires.

Forest growth, on the one hand, and the animals eating vegetation, combined with other natural factors like storms, fires, insect infestations, on the other are opposite forces, balancing each other over time and place, and this dynamic balance looks slightly different in time and space.

The molluscs from Borđoš

The molluscan fauna from Trench 2 at Borđoš (Hofmann, Medović *et al.* this volume) falls into four aquatic (Ložek 1964; Sümegi *et al.* 2022) and five terrestrial (Juřičková, Horsák, Horáčková, Abraham *et al.* 2014; Juřičková, Horsák, Horáčková, and Ložek 2014) ecological groups. Almost one fifth of the mollusc finds and 10 out of 22 of the species identified at Borđoš are of aquatic molluscs (species that prefer either periodically flooded areas, permanent standing water, slow-moving water, swamps, or river bed environments).

Woodland and open-habitat species (n=6) constituted 71.4% of all terrestrial species. Generalists are the most numerous in this group. Among them, *Euconulus fulvus* Müll. and *Punctum pygmaeum* Drap. prefer anthropogenic habitats (Juřičková, Horsák, Horáčková, Abraham, *et al.* 2014). Together, they make up almost half of all finds (46.4%). The samples yielded 6 open country – preferring species, representing 10.3% of all mollusc finds. Damp and alluvial woodland – preferring species (n=2) represent 0.2%.

Caucasotachea vindobonensis Pfeiff. (formerly *Cepaea vindobonensis* Fér.), a typical steppe and forest-steppe species (Ložek 1964) that can also inhabit various types of xeric grasslands, arid and humid scrublands, forest edges, tall grass vegetation and gallery forests along stream and riversides, as well as ruderal habitats, has a non-steppic origin (Kajtoch *et al.* 2017). *C. vindobonensis* and *Granaria frumentum* Drap. are associated with temperate forest steppe in both the Holocene record and the recent Great Hungarian Plain forest steppe (Sümegi *et al.* 2022). A concentration of a large number of *C. vindobonensis* shells was found in a house in the flat settlement at Borđoš, Trenches 4, 5, 8 and 9 (Hofmann *et al.* 2020).

The molluscan fauna at Borđš reflects mixed habitat types. Two major habitat types in the vicinity of Borđoš are aquatic and terrestrial. The existence of steppe and alluvial woodland, as well as woodland on the Late Pleistocene Terrace, is also indicated.

Environmental setting

In the Makaranda region, there are three distinct landscapes: the first is characterised by chernozem-like soil on higher topography, the second by solonetz soil (alkalinised soil) in somewhat lower topography in the north, and the third by hydromorphic soil in the lowest topography in the east (Nejgebauer *et al.* 1971; Hofmann, Medović *et al.* this volume).

In terms of its geomorphologic properties, humogley is a soil of the lowest parts of floodplain, lower river and loess terraces, and large depressions that were mainly under the permanent influence of groundwater – in some cases even up to the soil surface (Belić *et al.* 2011). Humogley soil is characterised by the appearance of groundwater that does not erupt to the surface and occurs in the higher parts of the alluvial plain or marshes. It covers a large proportion of the province of Vojvodina, especially the subregion of Banat, where it covers significant parts of extensive depressions or flooded terrain around the rivers Tisza, Begej, Tamiš and Danube. Humogley with high groundwater level is found under alluvial forests of pedunculate oak, ash and elm (Tomić *et al.* 2011). Yet, according to Slavnić (1952), the

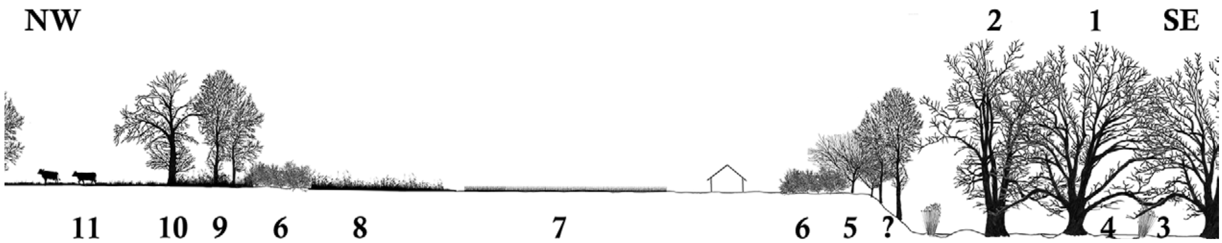


Figure 9. Vegetation reconstruction for the site of Makaranda (province of Vojvodina, northern Serbia) during the leafless period of the year based on logical inference and archaeobotanical and archaeological evidence, NW – SE profile. 1 Quercus robur *(pedunculate oak); 2* Ulmus *cf.* laevis *(European white elm); 3* Phragmites communis *Trin. (reeds); 4* Alisma plantago-aquatica *(common water plantain); 5* Cornus mas *(Cornelian cherry); 6* Prunus spinosa *(sloe); 7 crops (*Triticum monococcum *L. [einkorn] and/ or* T. timopheevii *Zhuk. [Zanduri wheat]); 8 grassland incl.* Stipa *sp. (feathergrass); 9* Ulmus *cf.* minor *(field elm); 10* Quercus *cf.* pubescens *(pubescent oak); 11 pasture land; (?) possibly Orno-Cotino-Quercetum pubescentis (see text for further explanation).*

oak – elm – ash lowland forest (*Fraxineto-Ulmetum effusa Ass.* nova Slav. 52) grows on the banks of rivers with running water and not in marshes along swampy river tributaries on humogley soil, as this lowland forest prefers older fluvisol. To understand the discrepancy between Slavnić's (1952) association and Tomić *et al.*'s (2011) findings, we have to bear in mind that during the Neolithic occupation at Borđoš, the River Tisza was located somewhat to the east in comparison to its modern location (Hofmann, Furholt *et al.* this volume). According to Parabućski and Janković (1978), the vegetational association of *Genisto elatae-Quercetum roboris* Horv. 38. is characteristic of older alluvial soils, but also of more developed alluvial soils, such as pseudogley and hydromorphic black soil. These forests can occupy areas that are not constantly flooded and areas that are flooded for a short period.

Mixed oak – elm – ash forests along large rivers have almost completely assembled tree floors, with an average tree height between 20 and 25 m. Exceptionally, in the most favourable conditions, the tallest trees can reach up to 35 m (Lakušić *et al.* 2005). The oak – elm – ash forest could have developed on the approximately 750 m wide hydromorphic black limeless soil strip located between the SE edge of the Late Pleistocene Terrace and the solonetz soil in the East (Nejgebauer *et al.* 1971).

Alkaline habitats cover an area of ca. 10 000 km^2 in the Carpathian Basin (Sümegi *et al.* 2013). Extensive alkaline landscapes are found in several parts of the Great Hungarian Plain, including the Danube – Tisza interfluve and the Körös – Maros interfluve. Vojvodina has significant areas (around 5% of the total) under halomorphic soil. They are insufficiently forested (Ivanišević *et al.* 2006). The dominant representative of this ecological zone is solonetz, alkalinised soil. These soils were in the past largely covered by common oak-ash and common oak-hornbeam forests. Today, the native pasture of the solonetz soil in the vicinity of Kumane is part of the halobiome of the Pannonian Plain (Knežević *et al.* 2009).

Several hypotheses, postulated mainly by botanists and pedologists (see Sümegi *et al.* 2013), point to human activity related to river regulation, starting during the second half of the nineteenth century, as being responsible for alkalinisation and the emergence of the modern ecosystem in the area of the Great Hungarian Plain. However, starting roughly 30 years ago, palaeoecological and palaeobiological studies unambiguously pointed to a natural origin for the alkaline steppe, dating back to the end of the last ice age (Sümegi *et al.* 2013) and showed that human activity associated with the arrival of the first farmers and agropastoralists barely affected the natural evolution of the area. Only in the nineteenth century did humans start to cause dramatic change in the landscape, by the drainage of marshlands and inundated areas, initiated roughly 160 years ago, followed by the introduction of rapidly intensifying farming. The expansion of crop farming and flood control, as well as drainage measures, fundamentally altered the hydrology in the vicinity of Borđoš (Fig. 4).

Based on recent research, it can be assumed that the prevailing vegetation on the Late Pleistocene Terrace during the Late Neolithic was something between grassland with patches of xerothermic shrubs and small trees, and xerothermic forest with patches of grassland (Hofmann, Medović *et al.* this volume).

Figure 10. Today, two isolated farmsteads (Serbian: salaš; Hungarian: szállás) with different house orientations (north-west – south-east and west – east) in the Koshava region (municipality of Žabalj) are protected from the SE wind with shrubs and trees. Photos taken 30 October 2023; aerial view Google Earth. Image: A. Medović.

Possible windbreak effect at Late Neolithic Makaranda

The house at Makaranda is at an angle of 45 degrees north-east (Fig. 2), at a distance of ca. 70 m from the edge of the Late Pleistocene Terrace and ca. 103 m from its base (Fig. 8). We presume that the canopy height of the oak – elm forest at the base of the Late Pleistocene Terrace was 25 m. For comparison, we note that in Slavonia (Croatia), the height of oak trees ranges from 10 to 37 m, and the height of elm trees ranges from 9 to 30 m (Rauš 1975). By subtracting the altitude of its base from the altitude of the terrace, we arrive at an effective height of the windbreak forest of 19 m (Fig. 9). Empirical values for a maximally effective wind-preventing range of the forest are approximately 150 m, or 5 to 7 times the height of the oak trees (Li *et al.* 2003; Středa *et al.* 2014). The maximum efficiency of this windbreak would be between the middle of April and the end of November.

The influence of the Koshava results in increased continentality, which could have resulted in in an increase forest cover on the eastern and south-east slopes of the Pleistocene terrace. The presence of a belt of *Q. pubescens* with a height of 10-15 m at the slope, together with *F. ornus* and *Cotinus coggygria* Scop., which are dominant in the stratum of short trees and bushes (Butorac *et al.* 2008), would only have improved the windbreak effect (Fig. 9).

Factors that could have influenced house orientation

As summarised by Müller-Scheeßel *et al.* (2020), a wide variety of theories have been proposed to explain house orientation during the Neolithic, relating to climate, the dominant wind direction, the ancestors, and sun exposure). Among the environmental factors, the prevailing wind direction has been rejected by most scholars as a major explanatory factor, but others are still under consideration (Vondrovský 2018), namely, the position of a house in relation to the Sun. The Sun's rays have an enormous influence

on a house's liveability, as the Sun is an abundant, natural source of light and warmth and consistent exposure to sunlight can help strengthen the immune system of the inhabitants and boost their mood (An *et al.* 2016). Time is intrinsically correlated with the Sun's path in both the daily and the seasonal sense, as the Sun's path defines the length of the day and the amount of daylight received along a certain latitude during a given season.

Non-environmental factors are also still considered to have explanatory power (Pásztor and Barna 2015). It is argued in anthropology that in each phase in the building of a traditional house, orientation is connected to a rite and that careful investigation of the orientation can reveal the attitudes of prehistoric people to their natural surroundings that involve not only the terrestrial, but also the celestial 'landscape', as an inseparable unity; the orientation of houses can be defined by the Sun, the Moon, and the stars, and it can reflect a system based on a cosmic view of time (Raczky and Anders 2010).

House energy efficiency

The environment around a building or house affects its energy consumption, primarily by influencing its requirement for heating and cooling of the internal space (Arens and Williams 1977). The environmental variables influencing the amount of energy needed for heating and cooling are outside temperature, humidity, solar radiation, and wind.

Thermophysical properties and thickness of house walls at Borđoš and Makaranda

According to Butorac and colleagues (2008), exposure of the SE and S slopes of the Late Pleistocene Terrace to the Koshava wind gives the climate pronounced continental characteristics, which is reinforced by additional effects of rain and extreme air temperatures effects during autumn and winter (Sturrock 1981). Consequently, thick house walls were needed to prevent heat-energy loss.

Thick daub walls were found at both Makaranda and Borđoš. The remnants of the walls of the burnt house in the flat settlement (Trenches 8 and 9) at Borđoš are up to 12 cm thick. The remnants of the walls at Makaranda are slightly thinner, up to 9 cm.

Earthen house structures (including wattle-and-daub structures) are considered to be naturally air-conditioned, whereby the rooms are cool at midday and warm at night (Asan and Sancaktar 1998; Hadji *et al.* 2020). There is a consensus in the literature that a key aspect of using earth as a construction material is the thermal inertia provided to the building. This thermal inertia is not enough to achieve thermal comfort in cold climates, but it is enough, when combined with other passive design strategies, to achieve thermal comfort without any active system in hot climates (Carrobé *et al.* 2021). Architects dealing with earthen houses consider the most important thing when constructing an earthen house to be understanding the climate and the location where the structure is being built. Wattle-and-daub structures are the most suitable in areas with a climate with high humidity and relatively moderate temperature. In intensely rainy areas, wattle-and-daub structures need rain protection. A roof with plenty of overhang will protect the walls from becoming soaked and hence softened in the rain. In colder climates, these structures often need additional thermal insulation for thermal comfort. Building materials significantly influence the thermal behaviour of the built walls. According to recent studies, the proportion of soil to straw that gives the best thermal performance, *i.e.* the lowest thermal conductivity, 5% by mass (Hadji *et al.* 2020).

Laboratory sample number	Borđoš Daub sample identifier	Coarse sand % 2-0.2 mm	Fine sand % 0.2-0.02 mm	Silt % 0.02-0.002 mm	Clay % < 0.002 mm	Texture (after Tom-merup)
11	9050/9003, A/3	56.26	27.70	12.12	3.92	coarse sandy loam
13	10075/10004, A/1	37.77	43.63	15.44	3.16	fine sandy loam
14	10077/10004, A/2	45.73	38.19	13.92	2.16	coarse sandy loam

Table 1. Mechanical composition and texture of daub samples from the Borđoš Late Pleistocene Terrace (province of Vojvodina, Serbia) (Trenches 9 and 10).

The wattle is daubed with a sticky material usually made of some combination of wet soil, clay, sand, and possibly animal dung and straw. In rural parts of Vojvodina, wattle-and-daub houses were constructed until the middle of the 20th century (Fig. 10).

This type of architecture is poorly preserved in European archaeological contexts unless accidental or intentional firing events burnt the daub, thus preventing its dissolution into the matrix of the archaeological deposits (Amicone *et al.* 2020). Daub heated to relatively low temperatures (less than 500°C) or for very short periods may go through some transformational processes and become more hardened but would not become truly sintered and thus would remain more susceptible to subsequent disintegration. But even if the daub is heated to a sufficient temperature for the clay to become sintered, its preservation in the archaeological record may be conditioned over time by the chemical composition of the soils, repeated drying and heating episodes, repeated cycles of freezing and thawing conditions, bioturbation, and later human activity (Kruger 2015).

The daub from Borđoš was analysed in the Laboratory for Soil and Agroecology at the Institute of Field and Vegetable Crops in Novi Sad for its mechanical composition and texture (Table 1). The results of the analyses showed that the daub consists mainly of coarse and fine sand and that the percentage of clay is very low. The texture of the analysed samples was described as ranging from fine sandy loam to coarse sandy loam. The high sand content in the soil assured that there was a limited amount of cracking once the mix had dried. In comparison with soil from the Late Pleistocene Terrace, the daub has significantly more coarse sand and less clay. Its mechanical composition and texture correspond better to the alluvial soil of the River Tisza (Živković *et al.* 1972).

Plant building material at Makaranda and Opovo

The organic building materials used in the Opovo structures comprised material from mixed vegetation as well as forests (Borojević 2006). The wood impressions in the daub of the house at the Late Neolithic site Opovo, ca. 60 km south of Borđoš, indicate that the wood used for house construction consisted of branches and of timber that had been split from thick tree trunks (Borojević 2006). Borojević suggested that oak was used for both primary and secondary house posts at Opovo. Impressions of reeds (*Phragmites communis*) in the Opovo house rubble indicate that there were marshes around the site.

Impressions of reeds could also be observed in the house daub at Makaranda. The wood impressions in this daub indicate that the wood used for house construction consisted of timber that had been split. Anthracological analyses could identify only oak.

Even though there is no evidence for roofing materials at Makaranda, we presume that the main thatching materials used were straw of einkorn, long straw of Zanduri wheat, reed, or various types of grasses – whatever would render the roof windproof.

Conclusion

Working on the assumption that the house at Makaranda was not a seasonal dwelling, we reconstructed the natural environment of the site of Makaranda site at the micro level, using a combination of archaeological, palaeo- and recent climatological, geomagnetic, macro-botanical, anthracological, palynological, and geomorphological findings from the site itself. as well as macro-botanical evidence from two other Neolithic sites on the Borđoš Late Pleistocene Terrace, Prečka and Borđoš, and from one palynological core at the foot of the terrace near Makaranda.

Palaeoclimatological research in the region unequivocally indicates the existence of a prevailing wind from the SE, known today as the Koshava, a cold wind that blows primarily in the winter, whose wind gusts exceed 100 km/h. Anthrocological results from all three Neolithic sites indicate the use of oak (*Quercus*) and elm (*Ulmus*) timber. Palynological research indicates the existence of extensive oak and elm forests near the Late Pleistocene Terrace. Geomorphological research at the Borđoš indicates the existence of forests, at least on the edges of the Late Pleistocene Terrace. Macro-botanical results from the house at Makaranda indicates the existence of wetlands near the settlement and of steppe vegetation in the vicinity of both Makaranda and Borđoš. Malacological results from the first Late Neolithic settlement at Borđoš show the existence of aquatic and terrestrial habitats in the area.

Based on direct and indirect findings, we conclude that the five houses at Makaranda, which were oriented NE – SW, were somewhat protected by standing vegetation. In winter, due to the lack of leaf mass, the impact of deciduous forest on the speed and effect of the wind would have been reduced by almost half from what it was at other times of the year. Protection against the natural elements, such as stormy or cold winds in this most vulnerable period of the year winter, and thereby thermal comfort in the interior of the house, could have been achieved by improving its thermophysical properties, by means of thick wattle-and-daub walls. We believe that these two design strategies – adequate windbreaks and thick wattle-and-daub walls – allowed the residents to build houses in the orientation they deemed appropriate for cultural reasons, even though this orientation per se was less optimal for thermal comfort reasons.

Today, there are significantly fewer areas under forest cover than there were in the Neolithic. Therefore, the question of whether the zone of influence of the SE wind was the same during prehistory as it is today remains unresolved, but we can assume that this zone expanded under the influence of human activities and deforestation.

Our case study of the Late Neolithic site of Makaranda has proven that a scarce botanical record from the archaeological investigation can be compensated for and supplemented with research results from other natural sciences and that only through a multidisciplinary approach is it possible to reconstruct the natural environment of an archaeological site at the micro level.

References

Amicone, S., Croce, E., Castellano, L. and Vezzoli, G., 2020. Building Forcello: Etruscan wattle-and-daub technique in the Po Plain (Bagnolo San Vito, Mantua, northern Italy). *Archaeometry*, 62 (3), 521-537.

An, M., Colarelli, S.M., O'Brien K., Boyajian, M.E., 2016. Why We Need More Nature at Work: Effects of natural elements and sunlight on employee mental health and work attitudes. *PLoS One*, 11(5), e0155614.

Arens, E.A. and Williams, P.B., 1977. The effect of wind on energy consumption in buildings. *Energy and Buildings*, 1 (1), 77-84.

Asan, H. and Sancaktar, Y.S., 1998. Effects of wall's thermophysical properties on time lag and decrement factor. *Energy and Buildings*, 28 (2), 159-166.

Banković, S. and Ranković, N., eds., 2009. *The national forest inventory of the Republic of Serbia: the growing stock of the Republic of Serbia*. Belgrade: Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia-Forest Directorate Belgrade.

Belić, M., Nešić, L., Ćirić, V., Vasin, J., Milošev, D. and Šeremešić, S., 2011. Characteristics and classification of gleyic soils of Banat. *Ratarstvo i povrtarstvo*, 48 (2), 375-382.

Binney, H., Edwards, M., Macias-Fauria, M., Lozhkin, A., Anderson, P., Kaplan, J.O., Andreev, A., Bezrukova, E., Blyakharchuk, T., Jankovska, V., Khazina, I., Krivonogov, S., Kremenetski, K., Nield, J., Novenko, E., Ryabogina, N., Solovieva, N., Willis, K. and Zernitskaya, V., 2017. Vegetation of Eurasia from the Last Glacial Maximum to present: key biogeographic patterns. *Quaternary Science Reviews*, 157, 80-97.

Bitog, J.P., Lee, I.-B., Hwang, H.-S., Shin, M.-H., Hong, S.-W., Seo, I.-H., Mostafa, E. and Pang, Z., 2011. A wind tunnel study on aerodynamic porosity and windbreak drag. *Forest Science and Technology*, 7 (1), 8-16.

Bohn, U. and Neuhäusl, R., 2000. *Karte der natürlichen Vegetation Europas Map of the Natural Vegetation of Europe. Maßstab/Scale 1 : 2 500 000*. Münster: Bundesamt für Naturschutz/Federal Agency for Nature Conservation.

Borojević, K., 2006. *Terra and silva in the Pannonian Plain: Opovo agro-gathering in the Late Neolithic*. Oxford: Archeopress.

Butorac, B., Igic, R., Anackov, G., Zlatković, B., Vukov, D. and Boza, P., 2008. *Orno-Cotino-Quercetum pubescentis* Ass. nova prov. on the slopes of Titel hill (Serbia). *Archives of Biological Sciences*, 60 (1), 83-92.

Carrobé, A., Rincón, L. and Martorell, I., 2021. Thermal monitoring and simulation of earthen buildings: a review. *Energies*, 14 (8), 2080.

Caudullo, G. and de Rigo, D., 2016. Ulmus – elms in Europe: distribution, habitat, usage and threats. *In:* J. San-Miguel-Ayanz, D. de Rigo, G. Caudullo, T. Houston Durrant, and A. Mauri, eds. *European atlas of forest tree species*. Luxembourg: Publication Office of the European Union, 186-188.

Charlton, R., 2010. *Fundamentals of fluvial geomorphology*. Repr. London: Routledge.

Collin, E., 2003. *EUFORGEN technical guidelines for genetic conservation and use for European white elm (Ulmus laevis)*. Rome: International Plant Genetic Resources Institute.

Collin, E., Bilger, I., Eriksson, G. and Turok, J., 2000. The conservation of elm genetic resources in Europe. *In:* C.P. Dunn, ed. *The elms*. Boston, MA: Springer, 281-293.

Coppedge, B.R. and Shaw, J.H., 1997. Effects of horning and rubbing behavior by bison (*Bison bison*) on woody vegetation in a tallgrass prairie landscape. *American Midland Naturalist*, 138 (1), 189.

Drapa, A. and Balaet, R., 2009. *The lakes Iron Gates I and II*. Presented at the international workshop on transboundary water resources management in south-eastern Europe, Sarajevo.

Đurišić, Ž., Bubnjević, M., Mikičić, D. and Rajaković, N., 2007. Wind atlas of Serbian region Vojvodina. *In: Proceedings of European Wind Energy Conference (EWEC 2007)*. Presented at the European Wind Energy Conference, Milano, Italy, May 2007.

Feurdean, A., Marinova, E., Nielsen, A.B., Liakka, J., Veres, D., Hutchinson, S.M., Braun, M., Timár-Gábor, A., Astalos, C., Mosburgger, V. and Hickler, T., 2015. Origin of the forest steppe and exceptional grassland diversity in Transylvania (central-eastern Europe). *Journal of Biogeography*, 42 (5), 951-963.

Feurdean, A., Perşoiu, A., Tanţău, I., Stevens, T., Magyari, E.K., Onac, B.P., Marković, S., Andrič, M., Connor, S., Fărcaş, S., Gałka, M., Gaudeny, T., Hoek, W., Kolaczek, P., Kuneš, P., Lamentowicz, M., Marinova, E., Michczyńska, D.J., Perşoiu, I., Płóciennik, M., Słowiński, M., Stancikaite, M., Sümegi, P., Svensson, A., Tămaş, T., Timár,

A., Tonkov, S., Tóth, M., Veski, S., Willis, K.J. and Zernitskaya, V., 2014. Climate variability and associated vegetation response throughout central and eastern Europe (CEE) between 60 and 8 ka. *Quaternary Science Reviews*, 106, 206-224.
Forman, R.T.T., 1995. *Land mosaics: the ecology of landscapes and regions*. Cambridge; New York: Cambridge University Press.
Gams, I., 1986. Da li je Vojvodina areal stepe, šumo-stepe, ili šume? *Glasnik Srpskog geografskog društva Bulletin de la Société serbe de geographie*, 66, 49-54.
Gavrilov, M.B., Marković, S.B., Schaetzl, R.J., Tošić, I., Zeeden, C., Obreht, I., Sipos, Gy., Ruman, A., Putniković, S., Emunds, K., Perić, Z., Hambach, U. and Lehmkuhl, F., 2018. Prevailing surface winds in northern Serbia in the recent and past time periods; modern- and past dust deposition. *Aeolian Research*, 31, 117-129.
Gburčik, V., Mastilović, S. and Vučinić, Ž., 2013. Assessment of solar and wind energy resources in Serbia. *Journal of Renewable and Sustainable Energy*, 5 (4), 041822.
Goderie, R., ed., 2013. *The aurochs, born to be wild: the comeback of a European icon*. Zutphen: Roodbont.
Grlić, L., 1990. *Enciklopedija samoniklog jestivog bilja*. Zagreb: August Cesarec.
Hadji, F., Ihaddadene, N., Ihaddadene, R., Betga, A., Charick, A. and Logerais, P.O., 2020. Thermal conductivity of two kinds of earthen building materials formerly used in Algeria. *Journal of Building Engineering*, 32, 101823.
Heisler, G.M. and Dewalle, D.R., 1988. Effects of windbreak structure on wind flow. *Agriculture, Ecosystems & Environment*, 22-23, 41-69.
Hofmann, R., Medović, A., Furholt, M., Medović, I., Stanković Pešterac, T., Dreibrodt, S., Martini, S. and Hofmann, A., 2020. Late Neolithic multicomponent sites of the Tisza region and the emergence of centripetal settlement layouts. *Praehistorische Zeitschrift*, 95(1), 305-309.
Horvat, I., Glavač, V. and Ellenberg, H., 1974. *Vegetation Südosteuropas*. Stuttgart: G. Fischer.
Hrnjak, I., Lukić, T., Gavrilov, M.B., Marković, S.B., Unkašević, M. and Tošić, I., 2014. Aridity in Vojvodina, Serbia. *Theoretical and Applied Climatology*, 115 (1-2), 323-332.
Ivanišević, P., Galić, Z., Rončević, S. and Pekeč, S., 2006. Stanišni resursi u funkciji povećanja šumovitosti Vojvodine. *Topola*, 177-178.
Juřičková, L., Horsák, M., Horáčková, J., Abraham, V. and Ložek, V., 2014. Patterns of land-snail succession in central Europe over the last 15,000 years: main changes along environmental, spatial and temporal gradients. *Quaternary Science Reviews*, 93, 155-166.
Juřičková, L., Horsák, M., Horáčková, J. and Ložek, V., 2014. *Ecological groups of snails use and perspectives*. Poster presented at the 7th European Malacological Congress, 7-11 September 2014, Cambridge.
Kajtoch, Ł., Davison, A., Grindon, A., Deli, T., Sramkó, G., Gwardjan, M., Kramarenko, S., Mierzwa-Szymkowiak, D., Ruta, R., Ścibior, R., Tóth, J.P., Wade, C., Kolasa, M., Egorov, R.V. and Fehér, Z., 2017. Reconstructed historical distribution and phylogeography unravels non-steppic origin of *Caucasotachea vindobonensis* (Gastropoda: Helicidae). *Organisms Diversity & Evolution*, 17 (3), 679-692.
Knežević, A., Stojanović, S., Nikolić, L., Đžigurski, D., Ljevnaić-Mašić, B., Ćupina, B. and Belić, M., 2009. Produktivnost biljnog pokrivača prirodnog pašnjaka na solonjecu u okolini naselja Kumane. *Acta herbologica*, 18 (1), 29-39.
Kruger, R.P., 2015. A burning question or, some half-baked ideas: patterns of sintered daub creation and dispersal in a modern wattle and daub structure and their implications for archaeological interpretation. *Journal of Archaeological Method and Theory*, 22 (3), 883-912.
Lakušić, D., Blaženčić, J., Ranđelović, V., Butorac, B., Vukojičić, S., Zlatković, B., Jovanović, S., Šinžar-Sekulić, J., Žukovec, D., Ćalić, I. and Pavićević, D., 2005. Staništa Srbije Priručnik sa opisima i osnovnim podacima. *In:* D. Lakušić, ed. *Staništa Srbije,*

Rezultati projekta 'Harmonizacija nacionalne nomenklature u klasifikaciji staništa sa standardima međunarodne zajednice'. Belgrade: Institut za Botaniku i Botanička Bašta 'Jevremovac', Biološki fakultet, Univerzitet u Beogradu, Ministarstvo za nauku i zaštitu životne sredine Republike Srbije, 684.

Li, F.-R., Zhang, H., Zhao, L.-Y., Shirato, Y. and Wang, X.-Z., 2003. Pedoecological effects of a sand-fixing poplar (Populus simonii Carr.) forest in a desertified sandy land of Inner Mongolia, China. *Plant and Soil*, 256 (2), 431-442.

Ložek, V., 1964. *Quartärmollusken der Tschechoslowakei*. Prague: Tschechoslowakische Akademie der Wissenschaften.

Magyari, E.K., 2011. Late Quaternary vegetation history in the Hortobágy steppe and middle Tisza floodplain, NE Hungary. *Studia Botanica Hungarica*, 42, 185-203.

Magyari, E.K., Chapman, J., Fairbairn, A.S., Francis, M. and de Guzman, M., 2012. Neolithic human impact on the landscapes of north-east Hungary inferred from pollen and settlement records. *Vegetation History and Archaeobotany*, 21 (4-5), 279-302.

Magyari, E.K., Chapman, J.C., Passmore, D.G., Allen, J.R.M., Huntley, J.P. and Huntley, B., 2010. Holocene persistence of wooded steppe in the Great Hungarian Plain. *Journal of Biogeography*, 37 (5), 915-935.

Magyari, E.K., Kuneš, P., Jakab, G., Sümegi, P., Pelánková, B., Schäbitz, F., Braun, M. and Chytrý, M., 2014. Late Pleniglacial vegetation in eastern-central Europe: are there modern analogues in Siberia? *Quaternary Science Reviews*, 95, 60-79.

Marković, S.B., Bokhorst, M.P., Vandenberghe, J., McCoy, W.D., Oches, E.A., Hambach, U., Gaudenyi, T., Jovanović, M., Zöller, L., Stevens, T. and Machalett, B., 2008. Late Pleistocene loess-palaeosol sequences in the province of Vojvodina, north Serbia. *Journal of Quaternary Science*, 23 (1), 73-84.

Mezősi, G., 2017. *The physical geography of Hungary*. Cham: Springer.

Moskal-del Hoyo, M. and Lityńska-Zając, M., 2016. Plant remains from the Late Neolithic settlement of Polgár-Bosnyákdomb. *Folia Quaternaria*, 84, 85-98.

Müller-Scheeßel, N., Müller, J., Cheben, I., Mainusch, W., Rassmann, K., Rabbel, W., Corradini, E. and Furholt, M., 2020. A new approach to the temporal significance of house orientations in European Early Neolithic settlements. *PLoS One*, 15 (1), e0226082.

Nádor, A., Thamó-Bozsó, E., Magyari, Á. and Babinszki, E., 2007. Fluvial responses to tectonics and climate change during the Late Weichselian in the eastern part of the Pannonian Basin (Hungary). *Sedimentary Geology*, 202 (1-2), 174-192.

Nejgebauer, V., Živković, B., Tanasijević, Đ.M. and Milković, N., 1971. *Pedološka karta Vojvodine 1:50000* (Soil map of Voyvodina 1:50000). Novi Sad: Institut za poljoprivredna istraživanja.

Paine, R.T., 1969. A note on trophic complexity and community stability. *American Naturalist*, 103 (929), 91-93.

Parabućski, S. and Janković, M., 1978. Pokušaj utvrđivanja potencijalne vegetacije Vojvodine. *Zbornik za prirodne nauke Matice srpske*, 54, 5-20.

Pásztor, E. and Barna P., J., 2015. Neolithic longhouses and Bronze Age houses in central Europe. *In:* C.L.N. Ruggles, ed. Han*dbook of archaeoastronomy and ethnoastronomy*. Heidelberg: Springer, 1307-1316.

Pekeč, S., Orlović, S., Katanić, M., Stojnić, S. and Drekić, M., 2017. Fenološka osmatranja hrasta kitnjaka (Quercus petrea Matt/Liebl.) i hrasta lužnjaka (Quercus robur L.) na području Vojvodine. *Topola*, 199-200, 11-20.

Pokrajinska skupštinska odluka o programu zaštite životne sredine Autonomne pokrajine Vojvodine za period 2016-2025. godine, 2016. Novi Sad: Skupština Autonomne pokrajine Vojvodine.

Popov, D., Marković, S. and Štrbac, D., 2008. Generations of meanders in Serbian part of Tisa Valley. *Journal of the Geographical Institute Jovan Cvijić, SASA*, (58), 29-42.

Raczky, P. and Anders, A., 2010. *Activity loci and data for spatial division at a Late Neolithic site-complex (Polgár-Csőszhalom: a case study)*. Paper presented at the

Leben auf dem Tell als soziale Praxis: Beiträge des Internationalen Symposiums in Berlin vom 26.-27. Februar 2007. Kolloquien zur Vor- und Frühgeschichte 14, Berlin: Dr. Rudolf Habelt GmbH, 143-163.
Rauš, Đ., 1975. Vegetacijski i sinekološki odnosi šuma u bazenu Spačva. *Glasnik za* šumske *pokuse: Annales pro experimentis foresticis*, 18, 225-346.
Romanić, Đ., 2016. *Dynamic characteristics of the Koshava wind.* Unpublished PhD dissertation, University of Belgrade, Belgrade.
Romanić, Đ., Ćurić, M., Jovičić, I. and Lompar, M., 2015. Long-term trends of the 'Koshava' wind during the period 1949-2010. *International Journal of Climatology*, 35 (2), 288-302.
Romanić, Đ., Ćurić, M., Zarić, M., Lompar, M. and Jovičić, I., 2016. Investigation of an extreme Koshava wind episode of 30 January-4 February 2014: extreme Koshava wind episode of 2014. *Atmospheric Science Letters*, 17 (2), 199-206.
Schumacher, M., Schier, W. and Schütt, B., 2016. Mid-Holocene vegetation development and herding-related interferences in the Carpathian region. *Quaternary International*, 415, 253-267.
Schweingruber, F.H., 1990. *Mikroskopische Holzanatomie: Formenspektren mitteleuropäischer Stamm- und Zweighölzer zur Bestimmung von rezentem und subfossilem Material* = Anatomie microscopique du bois = Microscopic wood anatomy. 3. Aufl. Teufen: Flück-Wirth.
Sipos, Gy., Marković, S.B., Gavrilov, M.B., Balla, A., Filyó, D., Bartyik, T., Mészáros, M., Tóth, O., Van Leeuwen, B., Lukić, T., Urdea, P., Onaca, A., Mezősi, G. and Kiss, T., 2022. Late Pleistocene and Holocene aeolian activity in the Deliblato Sands, Serbia. *Quaternary Research*, 107, 113-124.
Skok, P., 1972. *Etimologijski rječnik hrvatskoga ili srpskoga jezika, K – poni'*. Zagreb: Jugoslavenska akademija znanosti i umjetnosti.
Slavnić, Ž., 1952. Nizinske šume Vojvodine Die Niederungswälder der Vojvodina. *Zbornik Matice srpske za prirodne nauke*, 2, 17-38.
Středa, T., Malenová, P., Pokladníková, H. and Rožnovský, J., 2014. The efficiency of windbreaks on the basis of wind field and optical porosity measurement. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 56 (4), 281-288.
Sturrock, J.W., 1981. Wind constraints to agricultural productivity. *Weather and Climate*, 1 (1), 31.
Sümegi, P., Molnár, D., Náfrádi, K., Makó, L., Cseh, P., Törőcsik, T., Molnár, M. and Zhou, L., 2022. Vegetation and land snail-based reconstruction of the palaeoecological changes in the forest steppe eco-region of the Carpathian Basin during last glacial warming. *Global Ecology and Conservation*, 33, e01976.
Sümegi, P., Szilágyi, G., Gulyás, S. and Jakab, G., 2013. The Late Quaternary palaeoecology and environmental history of Hortobágy, a unique mosaic alkaline steppe from the heart of the Carpathian Basin. *In:* M.B. Morale Prieto and J. Traba Diaz, eds. *Steppe ecosystems*. Washington: Nova Science Publishers, 165-193.
Szelepcsényi, Z., Breuer, H., Kis, A., Pongrácz, R. and Sümegi, P., 2018. Assessment of projected climate change in the Carpathian region using the Holdridge life zone system. *Theoretical and Applied Climatology*, 131 (1-2), 593-610.
Szelepcsényi, Z., Breuer, H. and Sümegi, P., 2014. The climate of Carpathian region in the 20th century based on the original and modified Holdridge life zone system. *Open Geosciences*, 6 (3).
Szkordilisz, F. and Zöld, A., 2016. Effect of vegetation on wind-comfort. *Applied Mechanics and Materials*, 824, 811-818.
Tomić, Z., Rakonjac, L. and Isajev, V., 2011. *Izbor vrsta za pošumljavanje i melioracije u centralnoj Srbiji*. Belgrade: Institut za šumarstvo.
Tošić, I., Gavrilov, M.B., Marković, S.B., Ruman, A. and Putniković, S., 2018. Seasonal prevailing surface winds in northern Serbia. *Theoretical and Applied Climatology*, 131 (3-4), 1273-1284.

Tošić, I., Hrnjak, I., Gavrilov, M.B., Unkašević, M., Marković, S.B. and Lukić, T., 2014. Annual and seasonal variability of precipitation in Vojvodina, Serbia. *Theoretical and Applied Climatology*, 117 (1-2), 331-341.

Troen, I. and Petersen, E.L., 1989. *European wind atlas. Published for the Commission of the European Communities, Directorate-General for Science, Research, and Development*. Roskilde, Risø National Laboratory.

Unkašević, M., Tošić, I. and Obradović, M., 2007. Spectral analysis of the 'Koshava' wind. *Theoretical and Applied Climatology*, 89 (3-4), 239-244.

Vode Vojvodine, 2019. *GIS Vode Vojvodine* [online]. Available from: http://gis.vodevojvodine.com/visios/vodeVojvodineEksterna [Accessed 16 Aug 2021]

Vondrovský, V., 2018. Let the sunshine in: the issue of Neolithic longhouse orientation. *European Journal of Archaeology*, 21 (4), 528-549.

Vrndžić, S., 2020. *Predlog plana upravljanja spomenikom prirode 'Hrast lužnjak u dvorištu crpne stanice kod Kumana' za period od 2022. do 2029*. godine.

Wheeler, E.A. and Manchester, S.R., 2007. Review of the wood anatomy of extant Ulmaceae as context for new reports of late Eocene Ulmus woods. *Bulletin of Geosciences*, 329-342.

Wilkes, F., 2019. *Settlement and landscape development of the Borđoš plateau, Serbia*. Unpublished master's thesis. Kiel University, Kiel.

Živković, B., Nejgebauer, V., Tanasijević, Đ.M., Miljković, N., Stojković, L. and Drezgić, P., 1972. *Zemljišta Vojvodine*. Novi Sad: Institut za poljoprivredna istraživanja.

Neolithic settlement structures on the lower reaches of the River Tisza (Vojvodina, Serbia): The results of archaeo-magnetic prospection

Robert Hofmann, Kata Furholt, Aleksandar Medović, Martin Furholt, Fynn Wilkes, Ildiko Medović, Tijana Stanković Pešterac, Till Kühl, Sebastian Schultrich, Raško Ramadanski, Lenkskaya Martinova

Abstract

We present archaeo-magnetic plans of nine Neolithic (eight of them Late Neolithic) settlements, which were surveyed between 2014 and 2022 along the lower reaches of the River Tisza, in Autonomous Province Vojvodina, Serbia. The site of Borđoš and the Borđoš Late Pleistocene Terrace (a loess terrace) are published in several preliminary reports and represent an example of micro-regionally focused multidisciplinary research. Borđoš is a multicomponent site with a 9 ha tell and a 40 ha flat settlement with five ditches, which is situated on the left bank of the Tisza, in the Banat part of the Autonomous Province of Vojvodina. In the past few years, thanks to the more widespread use of magnetic measurement as an indispensable survey method in archaeological field investigation, our knowledge about enclosure ditches and tell settlements in the Carpathian Basin and the Lower Danube region has improved. In the past decade, eight Neolithic sites in the wider area around Borđoš and farther along the Tisza were investigated by archaeo-magnetic prospection and surface collecting. In this article, we provide a general overview and first results of our research project by presenting the archaeo-magnetic plans and their preliminary interpretation. In addition to describing each site, we discuss the variability of settlement structures within our study region. We then address the significance of enclosures and how they fit into the Late Neolithic tell-scape.

Keywords: *Neolithic, Vojvodina, Serbia, archaeo-magnetic prospection, circular enclosure, multicomponent site, settlement structure*

Introduction

In the Serbian Autonomous Province of Vojvodina (henceforth only called Vojvodina), the landscape is dominantly flat because of the alluvial plain of the river systems; river dams and floodplain forest are visible on the horizon. The region is delineated by the Fruška Gora Mountain in the south and the South Carpathian Mountains in the east. Vojvodina is one of the most prosperous agricultural regions of not only in Serbia but the Carpathian Basin, and perhaps it is not an exaggeration to say that it is one of the most advantageous in central Europe. This is largely due to the fertile black soils of the area (about 3/4 of the land is covered by chernozem on loess deposits and black hydromorphic soil). From a geographic point of view, it is an important principle that the river basin has always provided complex farming, with good arable land ensuring successful crop production, not only on floodplains, but also on the elevated, non-flooded chernozem-like soil on loess deposits. The lush pastures of the floodplains and the natural pastures on alkali soils in the intermittently flooded areas are excellent for livestock farming. From the appearance of the first villages, *i.e.* from the late 7th millennium BCE onwards, we can expect continuous cultivation and farming.

Since 2014, archaeological research has been carried out in Vojvodina in a long-term Serbian – German cooperation between the Museum of Vojvodina Novi Sad, the National Museum of Zrenjanin and the City Museum of Bečej (since 2019), the National Museum Pančevo (since 2020) and Kiel University. The starting point of our investigations were locally and micro-regionally centred investigations of the Neolithic settlement history of a Late Pleistocene Terrace (often called loess terrace) south of the modern town of Novi Bečej (Medović *et al.* 2014; Hofmann *et al.* 2019). At the centre of this research is the multicomponent settlement of Borđoš, which, at more than 50 ha and associated both Vinča and Tisza pottery styles, probably functioned as a central site within this micro-region. In line with developments in other regions of the Tisza[1] Valley and the western Balkans, our micro-regional investigations have shown that sites as large and as complex as Borđoš were the result of population aggregation processes that evolved from the late 6th millennium BCE onwards, starting from dispersed Early Neolithic settlement structures and relatively uniform pottery styles over a large geographical area. After 5300 BCE, a phase of regional differentiation started. It lasted until about 4700 BCE and manifested itself in, among other things, regionally differing Vinča and Tisza pottery styles.

Since on the micro-regional scale the underlying settlement processes can be reconstructed only incompletely, the Lower Tisza area was chosen as our enlarged working area (extended in comparison the Borđoš Late Pleistocene Terrace), in which the River Tisza operates as the main axis (the 'Axis Mundi of Neolithic Vojvodina'). We aimed to achieve two things by our enlargement of the study region.

The first thing we hoped to achieve is to clarify just how unique sites of the 'Borđoš type' were in this region and how large the spatial catchment area of such sites was. For the Upper and Middle Tisza regions, the existence of 'supersites' was suggested, which seem to have functioned as central nodes for larger catchment areas or 'territories' (Parkinson 2006, 139-144; Raczky and Füzesi 2017). Our investigations try to clarify whether similar settlement patterns also occur in the Lower Tisza region. For regional reconstructions of settlement and population dynamics, there are still considerable research deficits in the area of the former Yugoslavia, mainly due to the lack of systematic archaeological heritage management. Regional Neolithic settlement processes can therefore only be reconstructed in exceptional cases so far (*e.g.* Bosnia). This is especially true for the distribution area

1 We use the English name, Tisza, for the river name in this article. We are aware that in Serbian and Romanian it is spelled Tisa and in Ukrainian it is spelled Тиса.

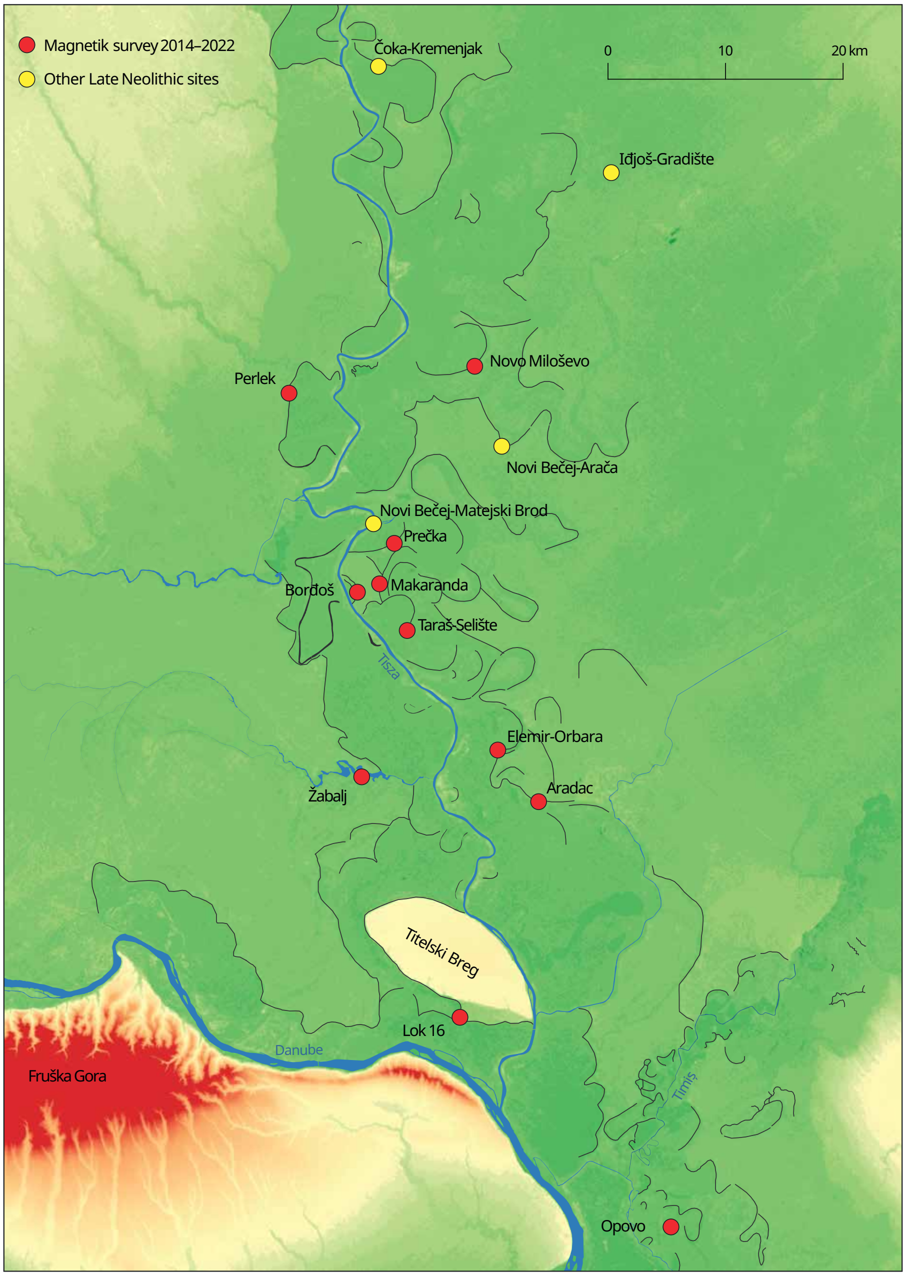


Figure 1. Map showing the study area, along the River Tisza, Vojvodina, Serbia, and the location of the sites mentioned in the text.

of communities with Vinča pottery styles (Chapman 2020, 287-291). Studies on the Neolithic settlement of the Carpathian Basin suggest that there is also a research gap in Vojvodina, especially along the Tisza (Chapman 1981, 421; Link 2006, Fig. 6). However, Serbian archaeologists are aware of a larger number of Neolithic sites which have not been subjected to closer study yet (Mirković-Marić and Marić 2017; Benjocki 2018; Marić and Mirković-Marić 2020). We also aim to establish whether noteworthy gaps in the distribution of Neolithic settlements along the Tisza are the result of research deficits. No Late Neolithic settlements are known from northern Bačka (Marić and Mirković-Marić 2020) or the region south of Zrenjanin, along the Tisza (Chapman 1981; Link 2006). These gaps may reflect a lack of archaeological exploration in these regions or they may be real, because, as a result of large-scale population aggregation processes, we would expect sparsely populated zones between dense clusters of sites.

The second thing we hoped to achieve was to understand the degree of spatial overlap in the distribution of the Tisza and Vinča ceramic styles in the study region. The spatial distribution of ceramic styles (often equated with archaeological cultures) is considered to be the result of intensified communication, and the study region is therefore designated as an area with increased communication density. Such an interpretation also seems extremely plausible given the density of the hydrological system, with the confluence of several important rivers, namely the Danube, the Tisza and the Timiş. Among other things, our investigations aim to clarify the extent to which this increased communication density and stylistic diversity is reflected in an increased plurality of settlement patterns and settlement layouts and how these patterns have developed over time.

In this article, we present archaeo-magnetic plans of nine mostly multiperiod settlements, as well as the preliminary results of our field investigations. These settlements are distributed over an approximately 80 km long stretch of the lower course of the Tisza, from Novo Miloševo in the north to the confluence of the Danube and Tisza near the Titel Loess Plateau in the south. By demonstrating the layout, size and spatial distribution of different settlement configurations, these archaeo-magnetic plans provide a sampling of the diversity seen within the study region, which will need to be further elaborated on and differentiated through future research.

Methods

Our multidisciplinary field research comprised three research phases, relating to three different levels of information. The primary field investigation consisted of field walking and geomagnetic prospection. After a first look at the collected material and the archaeo-magnetic plan, we evaluated whether there is any Neolithic relevance and added the site to our research list or not. Those Late Neolithic sites that show settlement structures with houses and/or other potential settlement features (*e.g.* ditches and pits) were dealt with in the second phase of the field investigation.

The second phase aimed to get more detailed information about the houses, mostly the burnt houses, and a cross-section of the ditch. This involved systematic fieldwalking, starting with the potential houses, whose location we identified based on the archaeo-magnetic map. Those houses with very strong magnetic signals could have massive burnt layers. Those houses located close to the fertile humus layer (topsoil) might be disturbed by ploughing or other agrarian activities, meaning there is a high chance that we will be able to find many finds on the surface, including diagnostic sherds or other well-known chronological markers, which we can compare later with the potential datable material from the drilling cores.

Until now, we have had only limited possibility to do the third phase of field investigations, namely coring, excavation and other natural scientific analyses (magnetic susceptibility, archaeobotanical and archaeozoological analyses). The drilling is a useful investigation method because it quickly provides information about the depth of the mentioned archaeological features, especially the ditch and how thick the burnt house layer. Besides confirming the relative position of archaeological features, drilling cores provide an excellent opportunity to find datable material. For instance, bone and charcoal samples were discovered in many cases, which are good for ^{14}C dating. Last but not least, the drilling cores also provide direct data for the environment reconstruction. The excavation trenches are small in size and target one specific house or ditch. This tertiary research process is the most time- and energy-consuming and requires at least a

minimal research funding budget and many motivated colleagues and students to spend many weeks in the field. Until now, only the sites of Borđoš, Prečka and Makaranda have been investigated by means of excavation, coring and natural scientific analyses (Medović *et al.* 2014, Medović *et al.* this volume; Stanković Pešterac *et al.* 2014; Hofmann *et al.* 2019; Hofmann, Medović *et al.* this volume). Opovo has also been subjected to this tertiary field investigation process with one exception, it has not been excavated yet by our Kiel-Novi Sad research team, although it has been excavated by the 1980s American-Yugoslavian research project. We have an active connection with Ruth Tringham, one of the project leaders of the 1980s project at Opovo and are integrating that project's work into our research as well (Tringham *et al.* 1985, 1992). The results from Opovo are not presented or discussed in depth here. They will be presented on another occasion.

Below, we describe the primary field investigation methods in detail.

Field walking

We set up a grid system by each investigated area before starting the field walking. The dimension of a grid field interfered by the local geomorphological and infrastructure conditions and the density of the surface finds. Our goal was to collect every find from all periods, to gain an overview of the entire site history and size. The documentation contains a short description, drawings and numbering of the grids, with the GPS coordinates for each corner of every grid. The finds were collected and documented by grids, except for diagnostic sherds or special finds (*e.g.* shaft-hole axes or clay figures), which were piece-plotted individually with a digital GPS system.

Magnetic survey

The archaeo-magnetic prospection was carried out with a GPS-supported 8-probe SenSys Sensorik & Systemtechnologie GmbH magnetometer (MX V3 Survey System, Bad Saarow, Germany). The measurement image has a resolution of 0.2 m. Depending on the field conditions, an area of between 5 and 15 ha can be surveyed per day. The data were processed by the SENSYS software and further processed in GIS software. The interpretation of the results is made by the involved scientists following a 'six-eyes principle' (Müller-Scheeßel *et al.* 2020) and by a GIS-based workflow (Hofmann *et al.* 2016, 166). The coordinates displayed in the magnetic plans refer to the UTM coordinate system, zone 34N in the World Geodetic System 1984 (EPSG 32634).

Surveyed sites

We surveyed a total of 11 sites between 2014 and 2022. Table 1 contains the basic dataset for each site and information about the period and the cultural association. An evaluation of the quantitative and qualitative data, as well as an illustration of the surface material, is beyond the scope of this article, so it will be published in another paper. The sites are sequenced based on the complexity of settlement in terms of settlement size and number of ditches and houses, starting with the most complex, the multicomponent site. Details of the location, archaeo-magnetic plan and settlement layout will be discussed in the following paragraphs. We present some information about Opovo and Prečka in Table 1, but we will not evaluate the plans in this article.

	Site name	District	Municipality	Cultural classification (prehistoric only)	Surveyed area (ha)	Settlement size (ha, reconstructed)	Number of visible houses	Number of enclosure ditches
1	Borđoš	central Banat	Novi Bečej	Neolithic (Tisza, Late Vinča), Bronze Age (Gáva – Belegiš I-II), Early Iron Age	54.3	A: 9 B: 1.4 C: 38	A: 33 B: 0 C: 104	A: 2 B: 2 C: 4-5
2	Žabalj-Nove Zemlje	southern Bačka	Žabalj	Neolithic (Starčevo, Tisza, Vinča), Copper Age (Baden), Bronze Age (Dubovac-Žuto Brdo group), Iron Age (Bosut and La Tène periods)	18.5	15.6	204	1-3
3	Opovo-Ugar Bajbuk	southern Banat	Opovo	Neolithic (Tisza, Late Vinča)	13.0	9.75	200-220	5
4	Perlek-Oranice Berkeša	central Bačka	Bečej	Neolithic (Tisza, Late Vinča)	7.5	≈7	17	4
5	Aradac-Kameniti Vinogradi	central Banat	Zrenjanin	Neolithic (Starčevo – Körös – Criş, Tisza, Early Vinča), Copper Age, Bronze Age (Transdanubian Encrusted Pottery), Early Iron Age	8.2	A: 4.3 B: >2.0	A: 84 B: 0	A: 3-4 B: 4
6	Taraš-Selište	central Banat	Zrenjanin	Neolithic (Starčevo – Körös – Criş, Tisza, Early and Late Vinča), Copper Age, Bronze Age, Early Iron Age	4.9	2.2	17	3
7	Elemir-Orbara	central Banat	Zrenjanin	Neolithic (Tisza, Vinča), Copper Age (Baden)	3.3	0.95	9	1
8	Makaranda	central Banat	Novi Bečej	Neolithic (Starčevo – Körös – Criş, Tisza, Early and Late Vinča), Bronze Age (Transdanubian Encrusted Pottery, Gáva – Belegiš)	8.5	≈1.9	5	0
9	Novo Miloševo-Peskana na rukundi	central Banat	Novi Bečej	Neolithic (Starčevo – Körös – Criş, Tisza), Copper Age (Bodrogkeresztúr)	7.7	?	0	0
10	Titel-Lok 16	southern Bačka	Titel	Neolithic (Starčevo – Körös – Criş, Tisza?, Early and Late Vinča?), Copper Age (Baden), Early Iron Age	6.1	?	0	1?
11	Prečka	central Banat	Novi Bečej	Neolithic (Starčevo – Körös – Criş), Bronze Age (Vatin), Early Iron Age	23.5	?	0	0

Table 1. List of the surveyed sites with the relevant settlement information. Borđoš: A=tell, B=circular enclosure, C=flat settlement. Aradac: A=north-west, B=south-east

Borđoš

In the beginning of the project, our work focused on the Late Neolithic settlement mound and the flat settlement of Borđoš, near Novi Bečej (Fig. 1) (Medović *et al.* 2014; Stanković Pešterac *et al.* 2014; Hofmann *et al.* 2019). The site was systematically investigated by means of archaeo-magnetic and geoelectric survey, surface collection, drilling prospecting and excavation, between 2014 and 2022. Over this time period, archaeo-magnetic survey and surface collection was also carried out at other Neolithic sites in the Borđoš micro-region (*e.g.* Borđoš Late Pleistocene Terrace).

The investigations at Borđoš show a dynamic in which continued aggregation of the population between 5000 and 4700 BCE led to the formation of a *c.* 50 ha, multicomponent settlement and the possible abandonment of smaller settlements (Hofmann *et al.* 2019; Medović *et al.* this volume). The investigations also show that the existing settlements on the Borđoš Late Pleistocene Terrace cannot have been the only a source of this population aggregation and that the catchment area was therefore probably larger. Borđoš consists of a tell (component A) of approximately 9 ha (7 ha interior surface area) and a flat settlement adjoining it to the south (component B). The size of the latter was reduced from the original, estimated at 40 ha to 25 ha, by lateral erosion of the Tisza. A third component is a

Figure 2. Interpretative plan of the magnetic survey at Borđoš.

circular enclosure (component C), about half of which is preserved. North of the tell (A) a zone of isolated burnt houses is situated (component D) (Fig. 2).

Originally, the three settlement components, A, B and C, each had a circular ground plan and were surrounded by 2 to 4 ditches. In the case of the flat settlement, differences in the density of the magnetic anomalies and the intersections of ditches indicate that the ditches were re-cut several times and the size of the enclosed area was adapted at least once, resulting in a significantly enlarged settlement size. The ditches are interrupted by numerous entrances, which, in the case of the outer ditch, show a very specific design with inwardly directed endings. In contrast, the double ditch system of the tell (A) component lacks indications of re-cuttings and lacks entrances. In the circular enclosure (C), the situation is different again, insofar as we found evidence that the two parallel ditches were open simultaneously. In the area of one gate, the ditches were interconnected by radial ditches (Hofmann, Medović *et al.* this volume). In both the tell and the flat settlement, the houses that are visible in the magnetic plan are oriented with their longitudinal axis towards the centre of the settlement. In the case of the tell, differences in surface density and fragmentation of the pottery suggest that there was an unbuilt space in the house-free centre of the settlement. A similar configuration is also plausible for the flat settlement. We are therefore probably dealing with centripetal layouts, which are currently being increasingly detected in the Tisza region and which we consider to be an expression of a mode of social organisation that values communal decision making to a higher degree than it is in an axial layout (Hofmann *et al.* 2019).

A larger series of ^{14}C dates shows that the tell (A) and the directly adjacent circular enclosure (C) probably represent the oldest components of the settlement, which was founded slightly before 5000 BCE. While the circular enclosure had already been abandoned around 5000 BCE, the tell was continuously inhabited until about 4600 BCE. The flat settlement (B), on the other hand, had a shorter duration, between about 4950 and 4700 BCE. The flat settlement is most likely the result of a phase of accelerated population aggregation, which is also detectable in other parts of the Pannonian Plain and the western Balkans, and which at Borđoš ended relatively abruptly around 4700 BCE (Medović *et al.* 2014; Stanković Pešterac *et al.* 2014; Hofmann *et al.* 2019).

Žabalj-Nove Zemlje

The Late Neolithic settlement of Žabalj is located on the south bank of the River Jegrička, a right tributary of the Tisza, 4 km north-east of the modern municipality (*opština*) of Žabalj (Serbian: Жабаљ; Hungarian: Zsablya). On the Third Military Ordnance Survey (MOS) (1819-1869), the site is shown positioned between the locations labelled ‘Ritski budžak’ and ‘Slatina’. There is a smaller elevation with water around it where the site was situated, and ‘Rankova hunká’ (Rankova hill) is marked as a higher point in the landscape (Biszak *et al.* 2007 a). On the Military Map of 1941, the site is bordered by the ‘Szikes’ (Serbian: Slatina) to the south and Zablyai folyás’ (Serbian: Jegrička bara) to the north (Fig. 3) (Timár *et al.* 2004).

Between 2018 and 2022, the site was fully prospected archaeo-magnetically, revealing a circular settlement complex originally about 20 ha in size, with ditches and numerous burnt houses from several phases. Surface collection yielded a mixed ceramic inventory with Tisza and Vinča ceramic styles, in addition to numerous tools. The settlement has been known since 1958, and already in 1965 its endangerment ‘due to agriculture and erosion of large areas of the settlement, especially the Neolithic’ was pointed out (Medović 1998, 83-84). Subsequent small-scale excavations in two locations showed that above the layers with Vinča-Tordoš pottery, there is a horizon with a younger Tisza pottery (Vilotijević 1965). From the excavations, only a short report and drawings of the diagnostic finds are available.

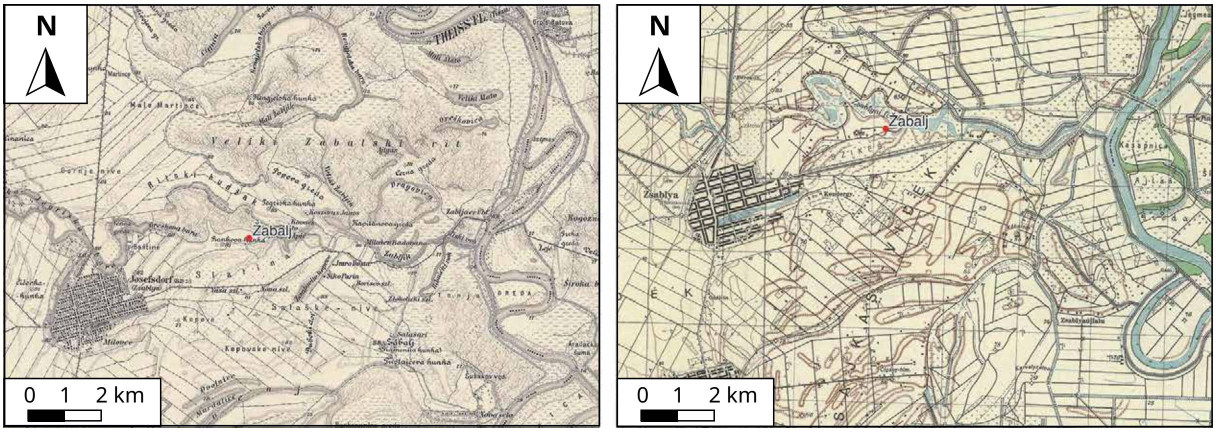


Figure 3. The location of the site of Žabalj superimposed on the Third Military Ordnance Survey (left) and the 1941 Military Survey (right) (Timár et al. 2004, 2010; Biszak et al. 2007 a; © Österreichisches Staatsarchiv [Third MOS (1869-1887) and Military Survey of Hungary (1941)].

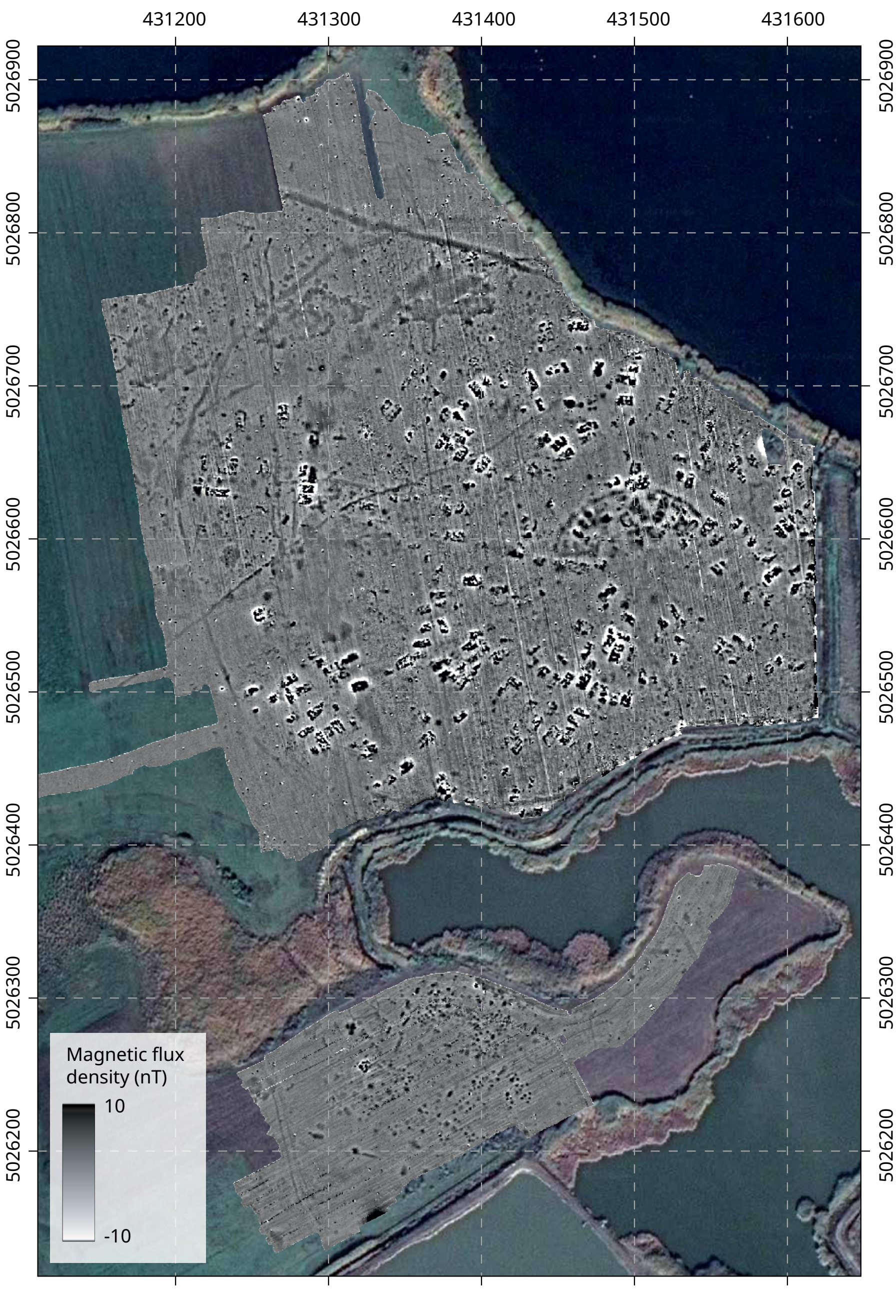


Figure 4. Plan of the archaeo-magnetic survey at Žabalj-Nove Zemlje.

Altogether, the surveyed area measures 18.5 ha. The River Jegrička forms the natural border of the magnetic survey. We were unable to survey the entire settlement structure because the north-eastern and southern parts are underwater. The modern channel path modification has flooded and probably destroyed those portions of the site (Fig. 4). The southern part of the prospected area did not show any specific structures. One cloudy anomaly of unknown origin is visible in the north-west corner, one burial mound in the central part and one rectangular-shaped anomaly in the middle of the north side.

The main prospected area shows a very dense settlement structure. There is one main linear anomaly, which encircles the settlement and is interrupted at several points. Its width ranges between 3 and 7 m, and its diameter is 380 m. Based on numerous analogies, this anomaly can be interpreted as a ditch that enclosed the settlement and of which approximately 60% is visible in the magnetic plan. In the southern part, the ditch becomes a bit narrower compared with the north-western and northern parts of it, and a less wide and less visible ditch-like structure, which has also a roundish shape, joins the main ditch. If the main circular ditch had been perfectly symmetrical, we would have seen part of it on the eastern part of the magnetic map, but it does not appear. This might indicate that the eastern part of the main ditch has a more oval or elongated shape or that the settlement structure has a different layout in this part.

There is another ditch fragment in the centre of the eastern part of the prospected area, which shows a circular form as well. However, only a very small part of it is visible. This ditch is 2-3 m wide, and the diameter was not measurable. Additionally, there are some linear anomalies in the northern and central parts. Two of these anomalies run parallel, in north-south direction, and another two crossing the plan, in NE – SW direction. A short linear anomaly is also visible in the north-west corner, also running in NE – SW direction.

In the western part of the prospected area, several cloudy structures of quite extensive dimensions are located. The vast majority of them follow the circular form of the main ditch. What kind of archaeological features these may represent and what their function may have been is still unclear. Around the cloudy anomalies, six burial mounds are visible, all of them circular with a single interruption.

Altogether, 204 anomalies of burnt houses can be identified. All of them are situated inside the main ditch, and the vast majority are concentrated in the southern and eastern parts. Their orientation is diverse, encompassing all kinds of directional combinations. The centre of the settlement could be localised in the east part of the prospected area, which is indicated by 10 burnt houses in radial position and a small dimension ditch fragment to the north of the houses. There is an intact area in the middle of the settlement's centre, which is a quite common feature in the enclosed and burnt house settlement layout in the Late Neolithic. The structures are not entirely symmetrical, but no overlapping or superposition is visible. In general, the dimensions of the houses are 8-10 m long and 5-6 m wide (Fig. 5).

Perlek-Oranice Berkeša

The site is located to the north of the modern town of Bečej (Serbian: Бечеј; Hungarian: Óbecse) and to the south of Bačko Petrovo Selo village (Serbian: Бачко Петрово Село; Hungarian: Péterréve), on the right bank of Tisza, in the southern part of the Bačka region (Рамадански *et al.* 2022). The Tisza is 4-5 km away from the site, and it shows two main curves today and on the historical maps. There is a small canal labelled 'Čik' (Csik or Csiki csatorna in Hungarian) 2-3 km to the north of the site. When the site location is overlain on the maps of the First MOS (1782-1785) (Biszak *et al.* 2007b) and the Second MOS (1819-1869), it is situated on the western part of a triangular, meadow-like floodplain (called Nagy Rét in

Figure 5. Interpretative plan of the magnetic survey at Žabalj-Nove Zemlje.

Hungarian, which means big meadow), 3 km from a village labelled Petrovoszello (Serbian: Bačko Petrovo Selo) (Timár *et al.* 2006). Next to the site, there was a road, which was probably a high bank of the floodplain, and at the same time, a natural border of the seasonal wetland and the dryer upper plain area. On the Second MOS map, this road is annotated in German with the words 'nach Szegedin', which means the road towards Szeged. The ditches of Perlek fit nicely with the mark of a high bank on the Second Military map (Fig. 6). There was common practice to use the remains of barrows and other earthworks (*e.g.* tells, fortified settlements and ramparts) as main markers of roads and administrative borders in medieval and

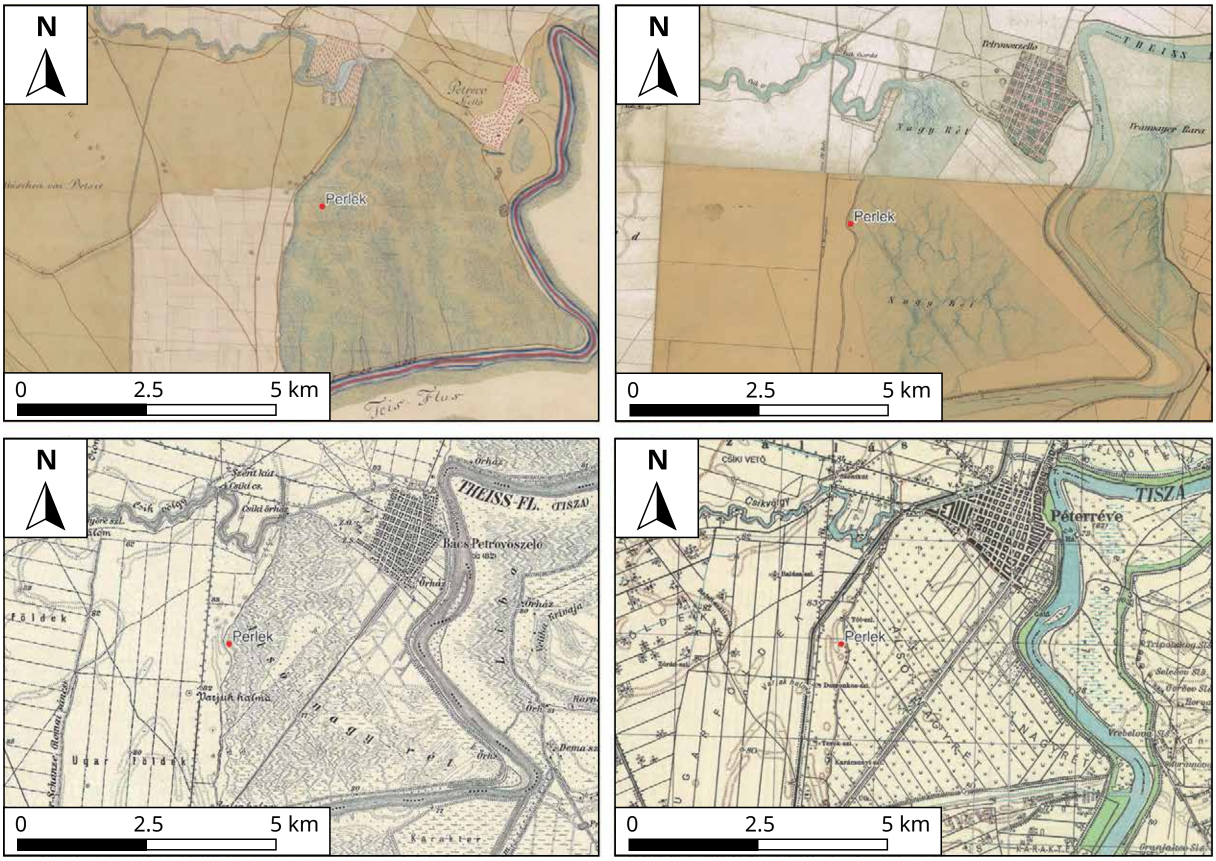


Figure 6. The location of the site of Perlek superimposed on the First MOS (top left); the Second MOS (top right); the Third MOS (bottom left); and the 1941 Military Survey (bottom right) (Timár et al. 2004, 2006; Biszak et al. 2007 a, 2007b; © Österreichisches Staatsarchiv ['First Military Survey (1763-1787)', Königreich Ungarn [B IX a 527], 'Second Military Survey of the Habsburg Empire (1819-1869)', Hungary [B IX a 1124], 'Third Military Survey (1869-1887)', 'Military Survey of Hungary (1941)']).

modern times (Bede 2016, 56-58), and for this reason, often these had their own names (*e.g.* one barrow to the south of Perlek was called Varjak halma, meaning barrow of the crows). In this line of the high bank, there are six barrows (probably Copper Age Yamnaya burial mounds) near the site, and there are more in the area (Przybyłar and Podsiadło 2021; Włodarczak 2021). Not all of these barrows (known as kurgans) are visible today. Probably many of them were destroyed during construction of the railway. Eight barrows are marked on the map of the Third Military map, but only four of them are visible on the military survey from 1941. Only the Third Military map shows the rampart of the Roman Empire (German: Römer-Schanze; Hungarian: Római sánc) 3 km to the west, which run the same direction as the high bank of Perlek (Timár *et al.* 2004, 2010; Biszak *et al.* 2007 a).

The archaeo-magnetic survey was carried out on the high bank, where the field was smooth, more or less straightforward, and constantly getting higher towards its western part. The site ends abruptly in the east, at a steep slope, due to a local difference in the surface level of several metres. The line of this elevation difference coincides with the missing part of the detected circular magnetic anomaly, thereby indicating that lateral erosion of the Tisza has destroyed the eastern part of the site. The circular anomaly is located on the eastern half of the prospected area, and it has smaller, rectangular anomalies within its boundaries. The roundish encircling anomaly probably reflects a ditch system containing two main ditches. The big one has an even, symmetrical circular shape, while the small one has a slightly square shape. Both circular anomalies are formed by two parallel ditches, which show several small, gate-like breaks (Fig. 7).

The outer and inner diameters of the main circular anomalies are 295 and 270 m, respectively, while those of the smaller ones are 170 and 120 m, respectively. The ditches are 2 to 4 m wide, being narrower along northern section and wider

Figure 7. Plan of the archaeo-magnetic survey at Perlek-Oranice Berkeša.

along the southern section. There are several parts where narrower, ditch-like anomalies are visible along the inner ditches. These are probably shallower features in comparison with the main enclosure system. The bigger ditch has four breaks, and the smaller one definitely has two and probably a third, which is just partly visible. The majority of these breaks were created with another small, ditch-like feature, which runs perpendicular to the main ditch lines, but such small features are not visible in every case. To understand the nature of the date-like structure, it is necessary to clarify it with a small-scale excavation.

There are 17 rectangular anomalies which probably indicate burnt houses. There are 10 potential buildings inside the inner ditch and another 7 between the inner and main ditches. The houses inside the inner ditch are situated close to each other, and four of them are in one line, with the same NE – SW orientation. Seven of the houses are oriented NE – SW, while the other two are oriented NW – SE. The houses between the two main ditches are arranged in a looser structure, with one house oriented NW – SE located in the northern part and six houses oriented NE – SW situated closer to each other in the southern part. The well-preserved rectangular remnants show dimensions of 10-15 m in length and 4-7 m in width (Fig. 8). During the two survey campaigns at the site, 7.5 ha were surveyed, and the remains of the ditch system with the houses cover 7 ha. The ditch system can be dated to the Late Neolithic based on the Tisza- and Vinča-style pottery recovered by surface collection during field walking.

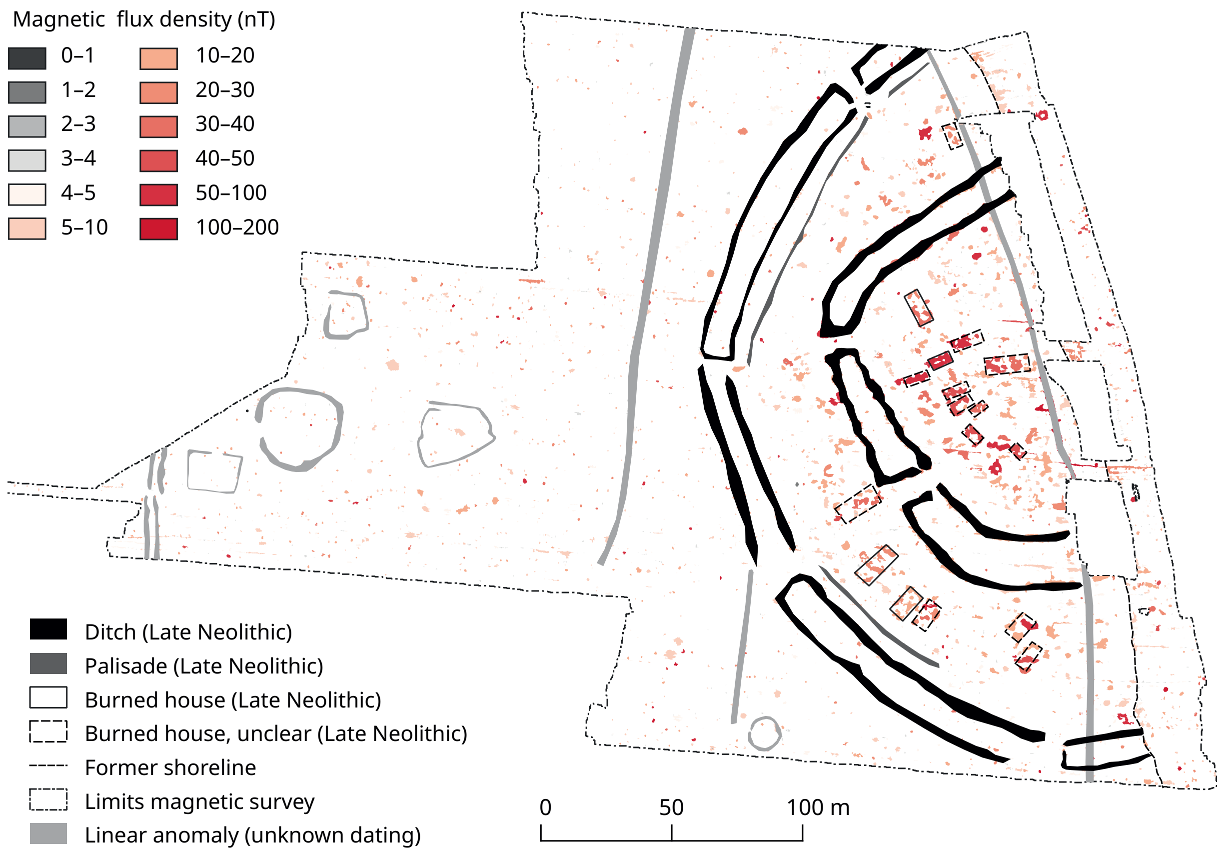


Figure 8. Interpretative plan of the magnetic survey at Perlek-Oranice Berkeša.

Aradac-Kameniti Vinogradi

This Neolithic site is located between the modern municipalities of Aradac and Zrenjanin (Serbian: Зрењанин; Hungarian: Nagybecskerek). The left bank of the Tisza is 5 km west of the site, and there is no creek or other smaller water watercourses near the site. The site is located on a small plateau (Fig. 9). On the Second MOS, the elevated part where the site is situated and called 'Konopinicze'. At present, most of the site is covered by vineyards (Kameniti Vinogradi means stone vineyards in English), which made surveying difficult.

At Aradac, we surveyed an area of 8.2 ha over the 2019 and 2022 campaigns. The resulting archaeo-magnetic map is very mosaic-like because of the vineyards but shows, nevertheless, the structure of the Neolithic settlement, which is situated on a gentle slope exposed to the south. In the investigated area are two spatially separated circular ditch systems, both of which consist of several ditches. The eastern ditch system is preserved over only about a quarter of its circumference. Most of this ditch system has been lost through lateral erosion by an old arm of the Tisza, which is nowadays completely silted up. This ditch system consists of an outer and an inner ditch circuit, each including two parallel ditches.

In the case of the northern ditch system, three to four more or less circular ditches, which are usually only partially visible in the survey results, enclose an area with a diameter of 200-210 m. This area contains at least 84 anomalies of houses. We can distinguish an inner zone surrounded by three ditches, with a high density of anomalies, from an outer zone, with only a few houses and a single ditch. The majority of the houses are oriented in NE – SW direction and show a dense structure, but no superpositioning is visible. Rectangular-shaped anomalies show dimensions of 6-9 m in length and 3-5 m in width. The magnetic signals of the houses are quite strong (Figs. 10 and 11).

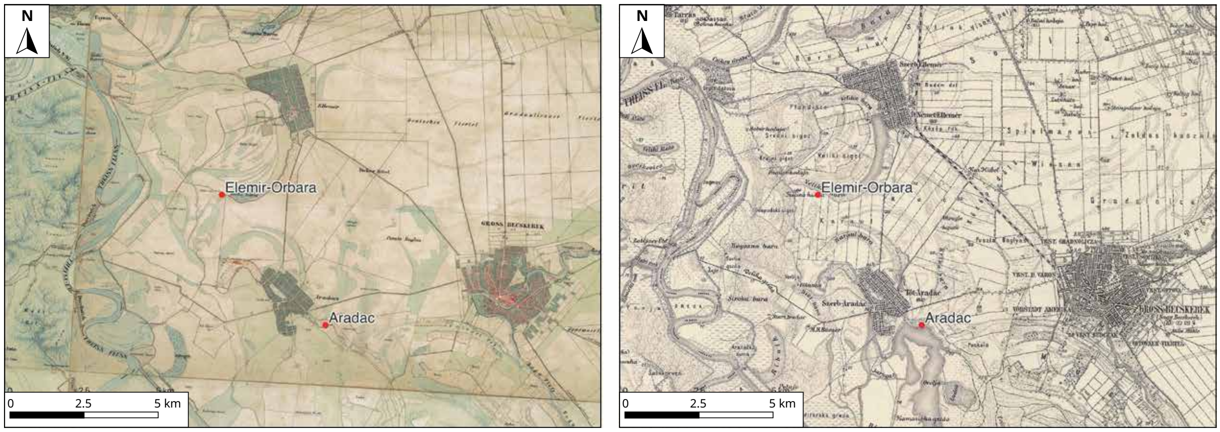


Figure 9. The location of the sites of Aradac and Elemir-Orbara superimposed on the Second MOS (left) and on the Third MOS (right) (Timár et al. 2006; Biszak et al. 2007 a; © Österreichisches Staatsarchiv ['Second Military Survey of the Habsburg Empire (1819-1869)', Hungary [B IX a 1124], 'Third Military Survey (1869-1887)']).

Figure 10. Plan of the archaeo-magnetic survey at Aradac-Kameniti Vinogradi.

The surface-collected material is very mixed, with Starčevo, Tisza, Vinča, Bronze Age and Migration-period pottery styles present. For this reason, we cannot conclude definitively that these ditches date to the Neolithic, but a Neolithic date seems the most likely. The northern settlement can be dated to the Late Neolithic based on both the structure and the surface material. The concentration of houses is visible in the central part of the area enclosed by the ditch.

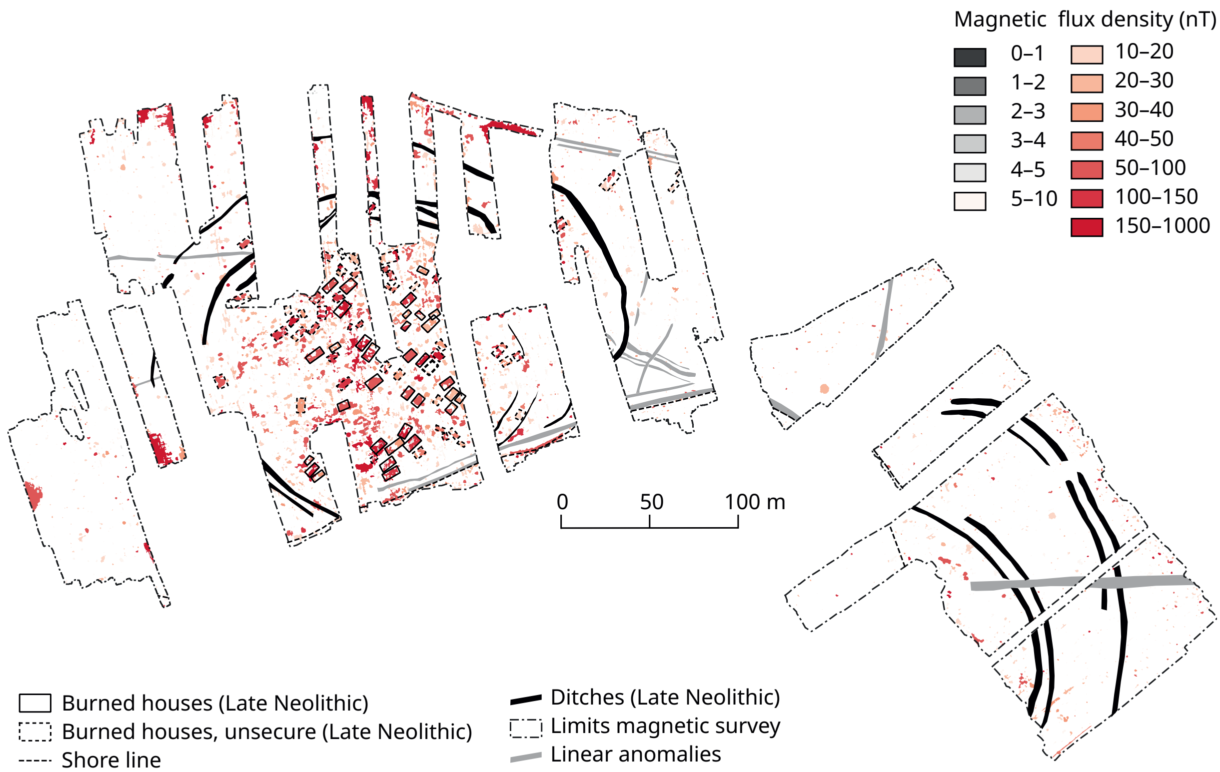


Figure 11. Interpretative plan of the magnetic survey at Aradac-Kameniti Vinogradi.

Taraš-Selište

Taraš is situated in central Banat, 2 km from the left bank of the Tisza, north of the modern-day village of Taraš (Serbian: Тараш; Hungarian: Tiszatarrós), south of the modern-day community of Kumane (Serbian: Кумане; Hungarian: Kumán). The Neolithic settlements Borđoš and Makaranda are located 4-5 km to the north. The site is located beside one of the old meanders (called Borđoš) of the Tisza, close to the Borđoš Late Pleistocene Terrace (Borđoš Loess Plateau) (Marković *et al.* 2005) (Fig. 12). On the Third MOS, this old meander is labelled 'Nagy viz' (a Hungarian term that means big water), and it is shown embracing the place labelled 'Veliki rit' (a Serbian term that means big marsh). Taraš was established at the point where this big meander meets a smaller, channel-like brook labelled 'Csíkos Graben' (the Hungarian word *csíkos* means striped; the German word *Graben* means ditch). There are many burial mounds in the area between Csíkos Graben and Tisza, and in this field are two smaller units labelled 'Veliko kopovo' and 'Duboko kopovo', which suggest salt-marsh territory. For this reason, it can be concluded that Taraš is situated between lusher, hydrologically conditioned vegetation and poor-quality salt-marsh regions, which could signify differences in land-use strategy. The site is nowadays located on chernozem soils, but in the surrounding area, hydromorphic soils dominate, as well as a large proportion of solonetz soils (soil map, Institute for Agricultural Research-Novi Sad (1971)).

The surveyed area is more or less one contiguous area with a total size of 4.9 ha. On the archaeo-magnetic map, two thirds of an enclosure ditch system is visible, consisting of three parallel, oval-shaped ditches (Figs. 13 and 14). The inner ditch has the strongest magnetic signal, while the other two have a weaker signal. A lower depth and different fill of the two outer ditches could explain their lower visibility and the fact that many parts are invisible. The inside diameter of the inner ditch is 112 m; the diameter of the outside ditch is not measurable because of the missing parts. Based on these anomalies, the settlement size can be estimated at 2.2 ha.

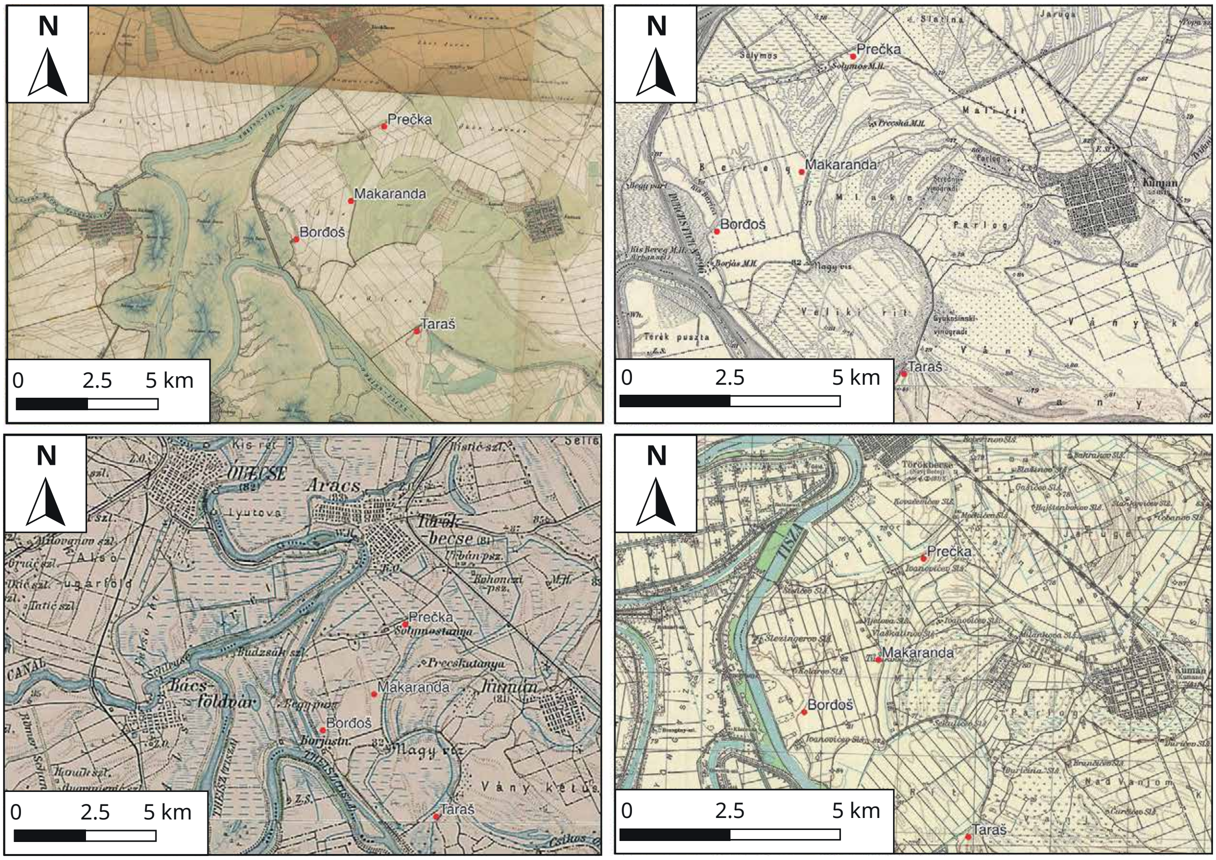


Figure 12. The location of the sites of Taraš, Makaranda, Prečka and Borđoš superimposed on the Second MOS (top left); the Third MOS (top right); the General Map of Hungary around 1910 (bottom left); and the 1941 Military Survey (bottom right) (Timár et al. 2004, 2004, 2006; Biszak et al. 2007 a; Bartos-Elekes 2016; © Österreichisches Staatsarchiv ['Second Military Survey of the Habsburg Empire (1819-1869)', Hungary [B IX a 1124], 'Third Military Survey (1869-1887)'] and © ELTE Térképtudományi és Geoinformatikai Tanszék ['General Map of Hungary around 1910']).

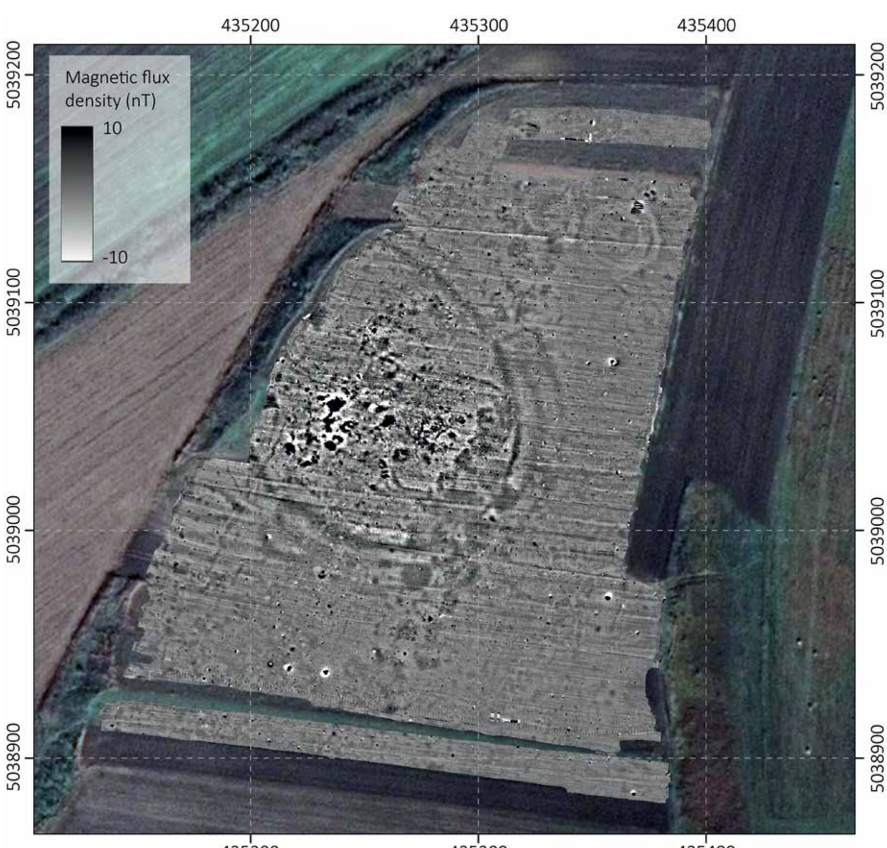


Figure 13. Plan of the archaeo-magnetic survey at Taraš-Selište.

Figure 14. Interpretative plan of the magnetic survey at Taraš-Selište.

The ditches are 3-5 m wide and look very similar in terms of dimensions. They show three potential gate structures on the north-east, south-west and south-east sides. The gate in the south-east shows a width of 15 m. The hypothesised gate on the south-east side of the enclosure is only 5-9 m wide. Both gates are indicated by traversal ditch segments that interconnect two or three of the ditches. Generally less clearly visible is the potential gate on the south-west side of the enclosure.

In the interior surface of the ditch system, 17 rectangular anomalies are visible, which can with some probability be interpreted as burnt houses based on our previous geomagnetic survey experience. Six of them are located close to the south-western part of the inner ditch and show a NW – SE orientation. Four

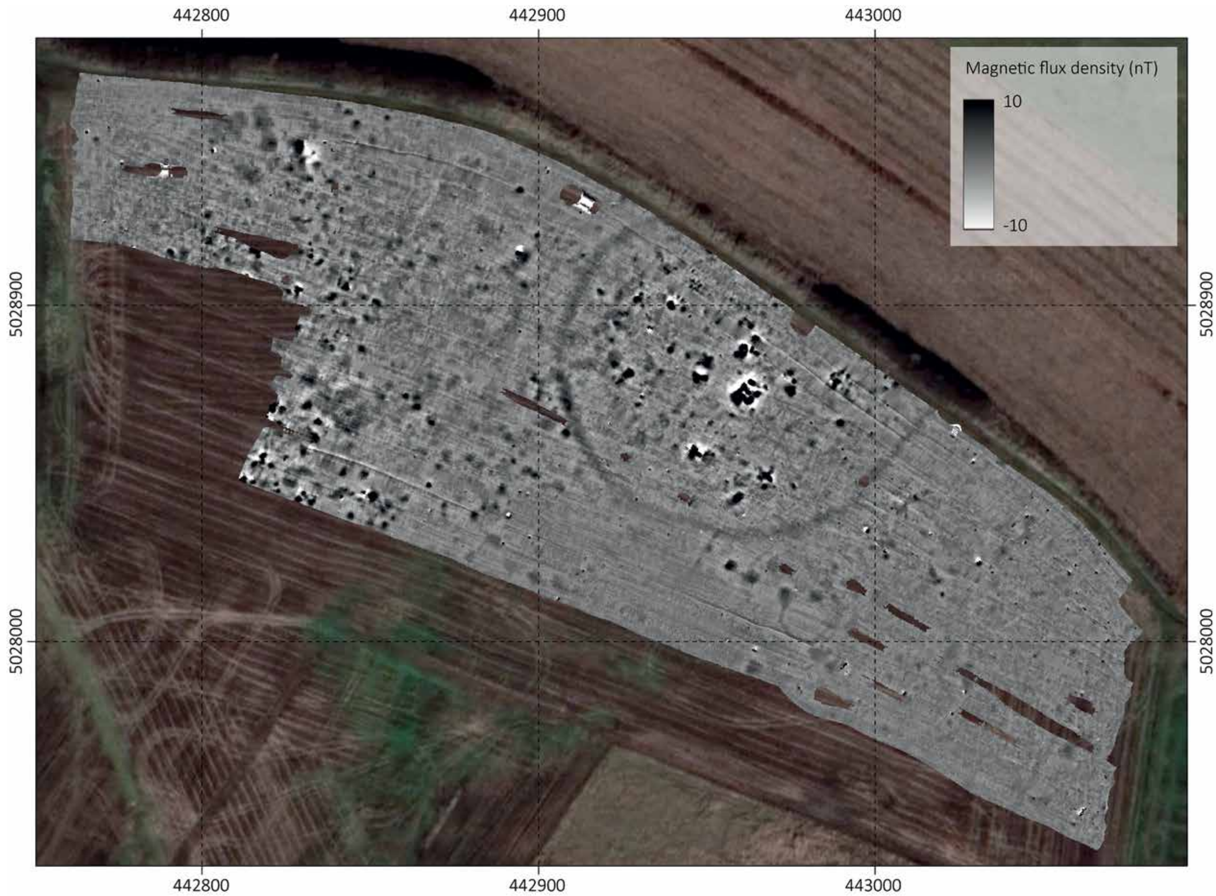


Figure 15. Plan of the archaeo-magnetic survey at Elemir-Orbara.

are placed in row close to each other, with their long walls paralleling each other. Two other houses are situated at some distance from each other in the western part. In the symmetrical middle of the ditch system, two houses are visible. The northern is oriented NE – SW, while the southern one is oriented NW – SE. The southern one is the only anomaly with a clear rectangular shape. The shape of the other anomalies is not completely clear, probably as a result of the displacement of daub through ploughing. The houses in the western part show dimensions of 4-6 m in length and 2-3 m in width in the western house accumulation. Nine possible houses in the east of the settlement seem to form a house row running parallel to the ditches. However, they show clearly weaker magnetisation than those in the centre of the site. The possible houses in the eastern part are longer than those in the western part, around 7 m.

On the surface, in addition Tisza, Vinča and Bronze Age pottery styles, there was a lot of probably medieval or later material visible, *e.g.* brick and other stone fragments, which probably interfered with the representation of the settlement structure in our magnetic survey. A medieval settlement (9th and 10th centuries AD) is known to have existed along the ridge of the Borđoš Late Pleistocene Terrace. In the 1950s, Serbian archaeologists excavated parts of a church in this area (Nađ 1952).

We are probably dealing with a small, Late Neolithic settlement at Taraš, whose circular shape, parallel ditches connected by radial ditches and (four?) gates facing each other show very strong similarities to circular ditch complexes. On the other hand, the site is clearly identified as a settlement due to its size and the remains of burnt houses.

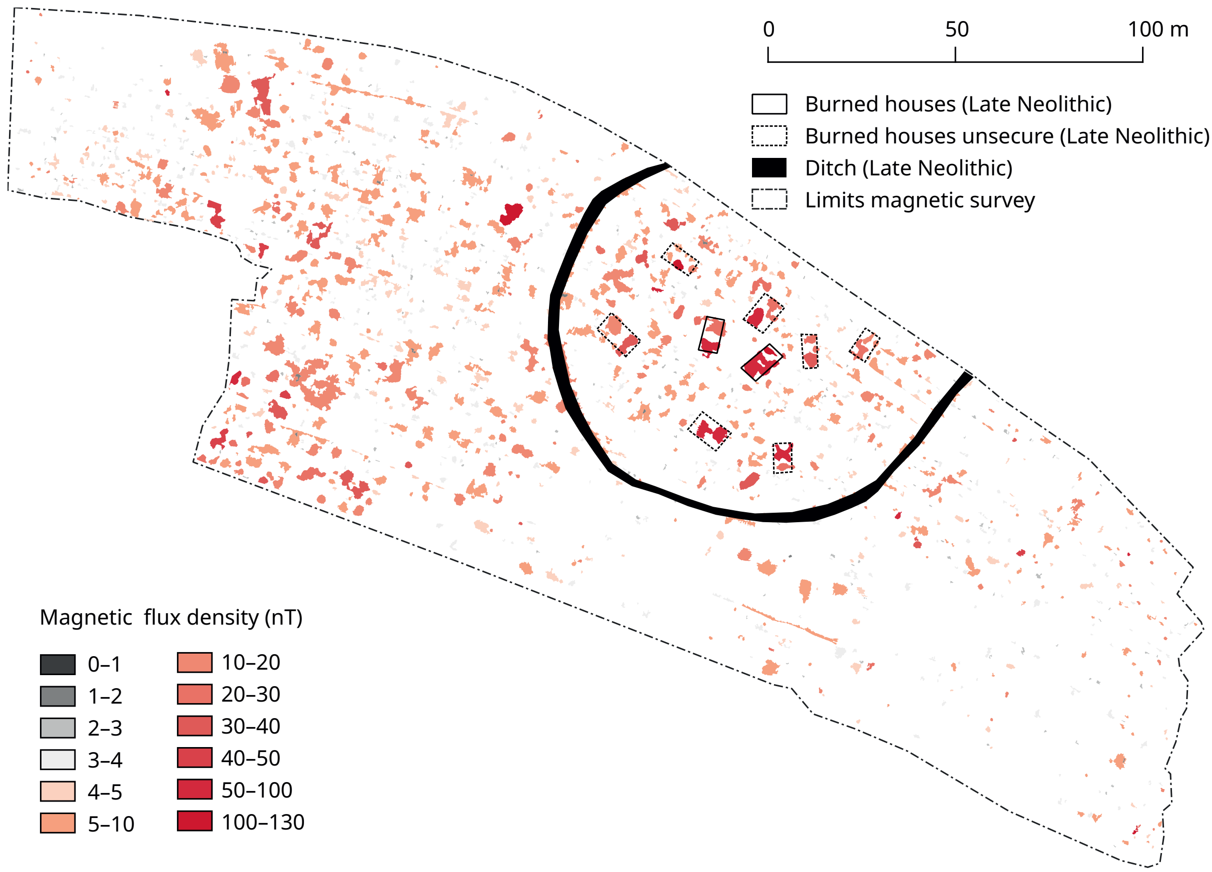


Figure 16. Interpretative plan of the archaeo-magnetic survey at Elemir-Orbara.

Elemir-Orbara

The site is located 4 km from the left bank of the Tisza, between Elemir (Serbian: Елемир; Elemér) and Aradac (Serbian: Арадац; Hungarian: Aradi) in central Banat. The site is situated 6 km north of the Late Neolithic site of Aradac-Kameniti Vinogradi and 12 kilometres from Žabalj-Nove Zemlje. The site is located next to an old meander (Serbian: Velika bara); other than that, no specific fix-points are visible on the historical maps (Fig. 9). On the Third MOS, the area to the north of the site is labelled 'Veliki siget' and that to the west is labelled 'Gospodski siget'. There was a hill-like point, which was probably a burial mound, to the west of the site; this is labelled 'Kucina hunká' (Kucina hill in English). The natural environment and human-modified landscape with the visible burial mounds suggests that the Late Neolithic Elemir site has a similar situation to Žabalj and Perlek.

One circular anomaly is visible on the archaeo-magnetic map, which can be interpreted as a single ditch. The width is between 2.5 and 4 m, and the diameter is 102 m. The north-eastern part of the ditch was not measurable because, here, the site is partly destroyed through lateral erosion of the adjacent (now-silted-up) river arm. Four rectangular-shaped houses are located in the interior space of the ditch; these are 6-9 m in length and 5-6 m in width (Figs. 15 and 16).

Makaranda

The multiperiod site of Makaranda is located on the eastern border of the Borđoš Late Pleistocene Terrace, where it directly adjoins a now-silted-up oxbow lake of the Tisza. The Late Neolithic sites of Prečka, Borđoš and Taraš are very close by. Makaranda is situated in an area of heavy agricultural activity, with the towns of

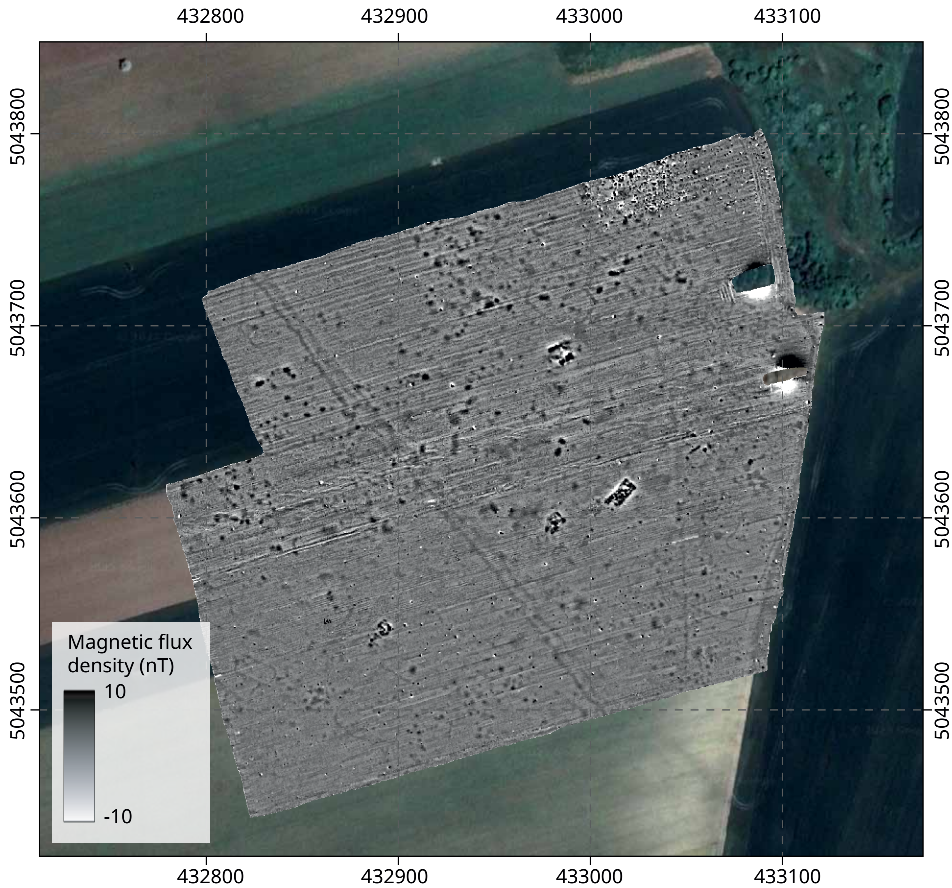


Figure 17. Plan of the archaeo-magnetic survey at Makaranda.

Novi Bečej (Serbian: Нови Бечеј; Hungarian: Törökbecse) to the north and Kumane (Serbian: Кумане; Hungarian: Kumán) to the south-east. On the Second Military map, the easternmost point of the area, labelled 'Borjas', is indicated as an area elevated from the surface, with meadows to the east. On the Third Military map, the Borđoš area is labelled 'Bereg', while the area east of Makaranda is labelled 'Mlake' (Fig. 12).

The site of Makaranda was surveyed in 2018, and this included systematic and non-systematic surface collections and an archaeo-magnetic survey on an area of 8.5 ha. The surface find material indicates a strong Late Neolithic occupation at the site, but Early Neolithic, Bronze Age and Late Antique material was found as well. The main features of this survey are five rectangular anomalies, which are interpreted as houses (Figs. 17 and 18). In 2018, a test excavation at one of these anomalies confirmed this interpretation. The results of the test excavation at Makaranda have been published in part (Wilkes 2019, 28-43; Wunderlich *et al.* 2022; Medović *et al.* this volume) and have been the subject of theses and dissertations (Autenrieth 2015; Martini 2019; Wilkes 2019).

Four of the five burnt houses visible in the magnetic plan are situated along a line running ENE – WSW. However, so far there is no information that allows us to answer the question to what extent the houses represent sequential occupations or whether we are dealing with a small hamlet consisting of several houses in use at the same time. The fact that the houses do not form a row in the strict sense and do not seem to be directly related to each other spatially could speak more for the former scenario. Test excavations of one of the buildings confirmed the existence of a burnt house with a massive platform raised from the ground. Two ^{14}C dates obtained from cattle bones from this context are inconsistent: 5287-5067 cal BCE

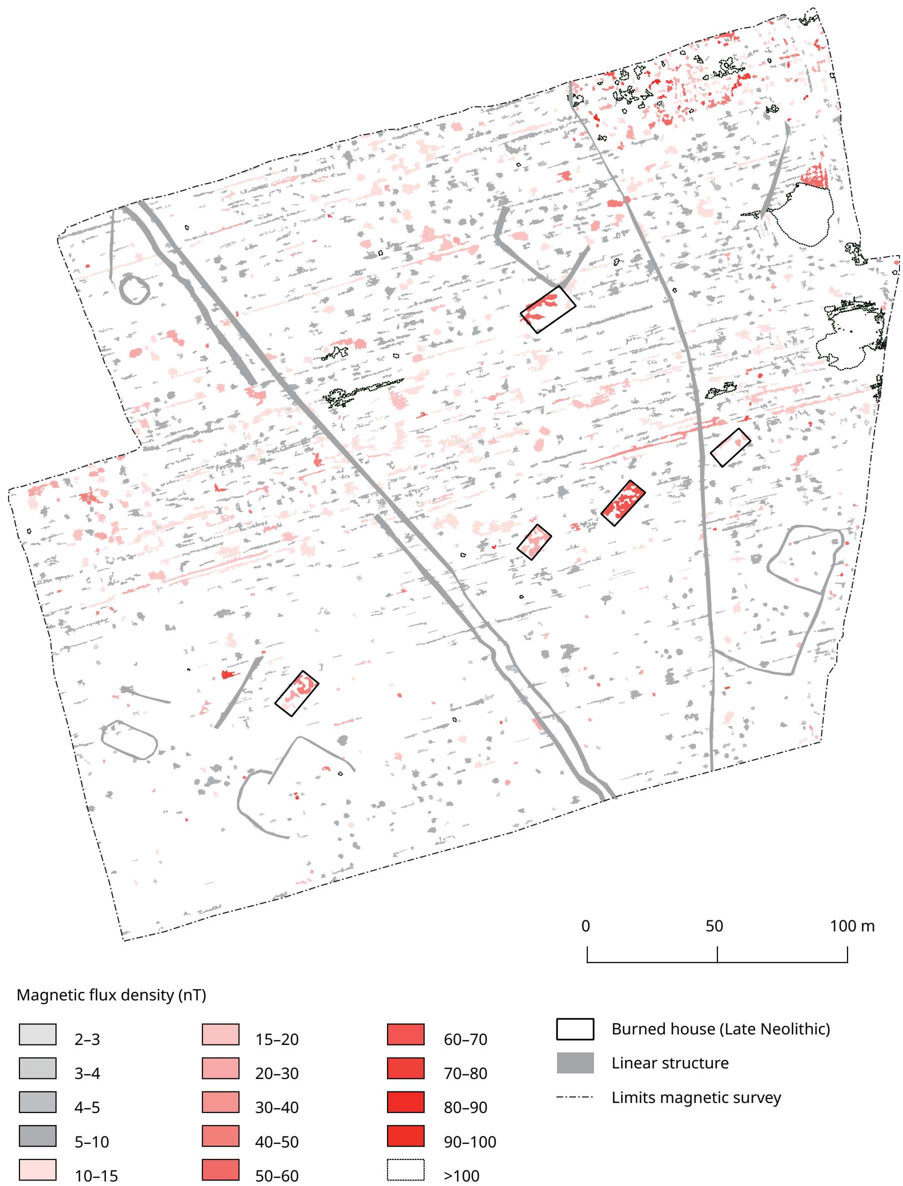


Figure 18. Interpretative plan of the archaeo-magnetic survey at Makaranda.

and 4938-4842 cal BCE (both 68.3%). No information is yet available on the character and chronology of the numerous oval, amorphous and linear anomalies at the site, although at least some are not of Neolithic age. The surface collection is indicative of the Neolithic Starčevo and Vinča communities, the Late Bronze Age Belegiš group, and the Sarmatian occupation.

Novo Miloševo-Peskana na rukundi

The northernmost site in the study area is Novo Miloševo, located 4 km south-west of the village of Novo Miloševo (Serbian: Novo Милошево; Hungarian: Beodra), 7 km east of the Tisza in the Banat region. The Late Neolithic site called Iđoš-Gradište is situated about 14 km to the north and Perlek is situated about 16 km away, on the Bačka side of the Tisza. The site of Novo Miloševo is located on the remains of an elongated Late Pleistocene Terrace (loess terrace), which is adjoined to the west by a silted-up oxbow of the Tisza. Apparently, part of the Late Pleistocene Terrace was eroded by lateral erosion of the Tisza. In the south of the surveyed area, pits with Early Neolithic Starčevo – Criş –

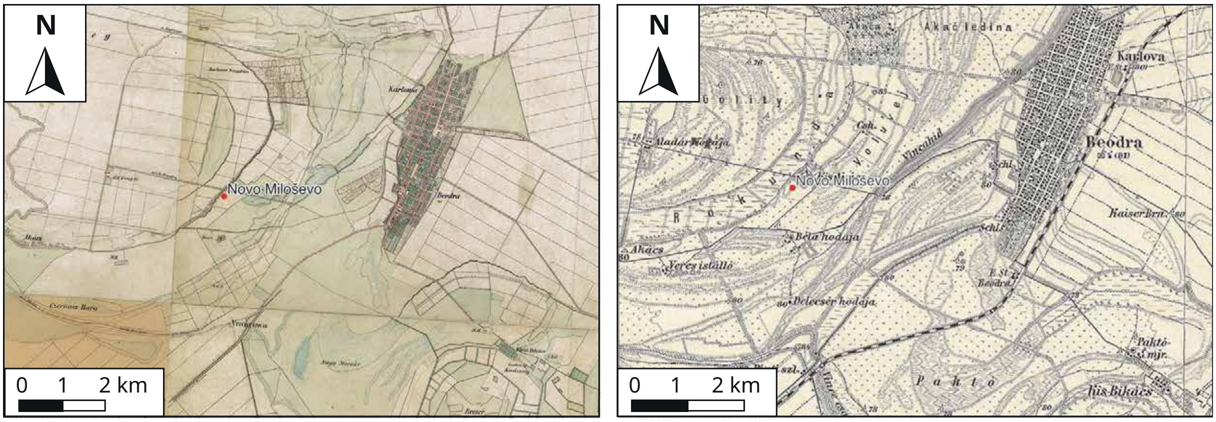


Figure 19. The location of the site of Novo Miloševo superimposed on the Second Military Ordnance Survey (left) and on the Third Military Ordnance Survey (right) (Timár et al. 2006; Biszak et al. 2007 a; © Österreichisches Staatsarchiv [Second military survey of the Habsburg Empire (1819-1869), Hungary [B IX a 1124]; „Third Military Survey (1869-1887)]).

Figure 20. Plan of the archaeomagnetic survey at Novo Miloševo.

Körös finds were documented in the profile walls of a sand quarry. In addition, Copper Age Bodrogkeresztúr graves were found in the vicinity of the site.

On the map of the Second MOS, the site is placed west of the medieval settlement of Beodra, which is presumably located along the arc of the former meander of the Tisza, which is labelled 'Rokunda' on the map of the Third MOS. The two burial mounds to the north and south of the site are marked as elevated points in the area on the Third MOS map, but they are not named (Fig. 19).

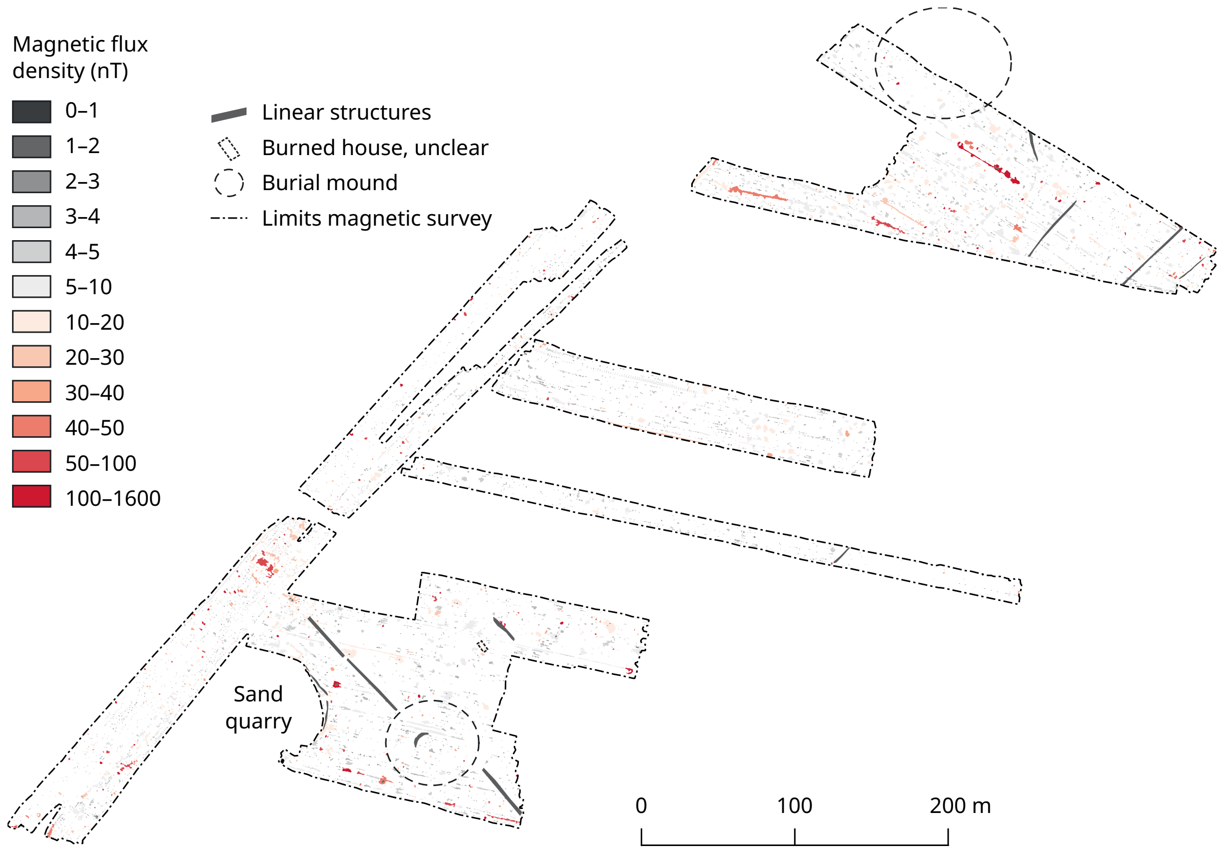


Figure 21. Interpretative plan of the archaeo-magnetic survey at Novo Miloševo.

The prospected area is very mosaic-like due to the limited time available for our field activities (Fig. 20). In the northern part of the surveyed area, east of the northern burial mound, three linear structures are visible. These are quite small fragments and therefore their relation to each other is not clear. In the middle part of the prospected area, a linear anomaly is detectable over a length of 17 m, which could be part of these northern anomalies based on their direction. Only one possible burnt house, of unknown age, was detected in the southern part of the prospected area (Fig. 21). In the area around the sand quarry and around a burial mound to the south, some faint amorphous anomalies are visible, which may be pits of an Early Neolithic settlement. However, these anomalies do not show clear structures and still require archaeological confirmation with regard to their dating.

Titel-Lok

This site is located on the south-western edge of the Titel Loess Plateau, a roughly circular plateau rising out of the alluvial plain and forming an island in the landscape. In the west and south, the plateau is limited by steep slopes towards the floodplain of the Danube (Fig. 22). From the point of view of transport geography, the site has an exceptional geographical position. The confluence of the rivers Tisza and Begej is 6 km to the east, and the Tisza runs into the Danube 7 km south-east of the site. The site is situated 1.5 km east from Lok and 4 km west from Titel. The height of the main plateau is around 120 m. The smaller, southern part of the plateau, where the site is located, is between 80 and 90 m heigh, based on the elevation data of the Third MOS.

An archaeo-magnetic survey was carried out at Titel-Lok in 2019 and 2022. The surveyed area measures 6.1 ha and consists of three parts. Some surface

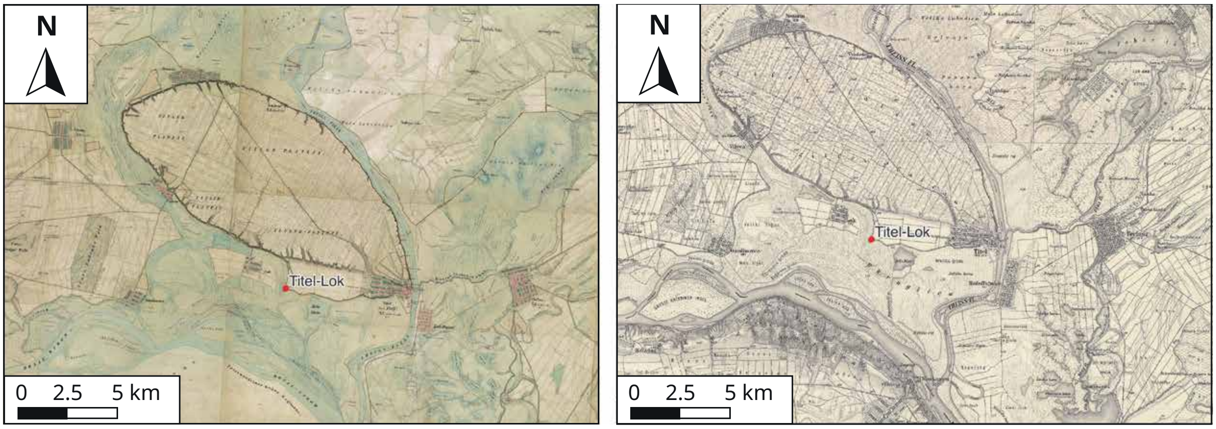


Figure 22. The location of the site of Titel-Lok superimposed on the Second MOS (left) and on the Third MOS (right) (Timár et al. 2006; Biszak et al. 2007 a; © Österreichisches Staatsarchiv [Second military survey of the Habsburg Empire (1819-1869), Hungary [B IX a 1124]; Third military survey (1869-1887)]).

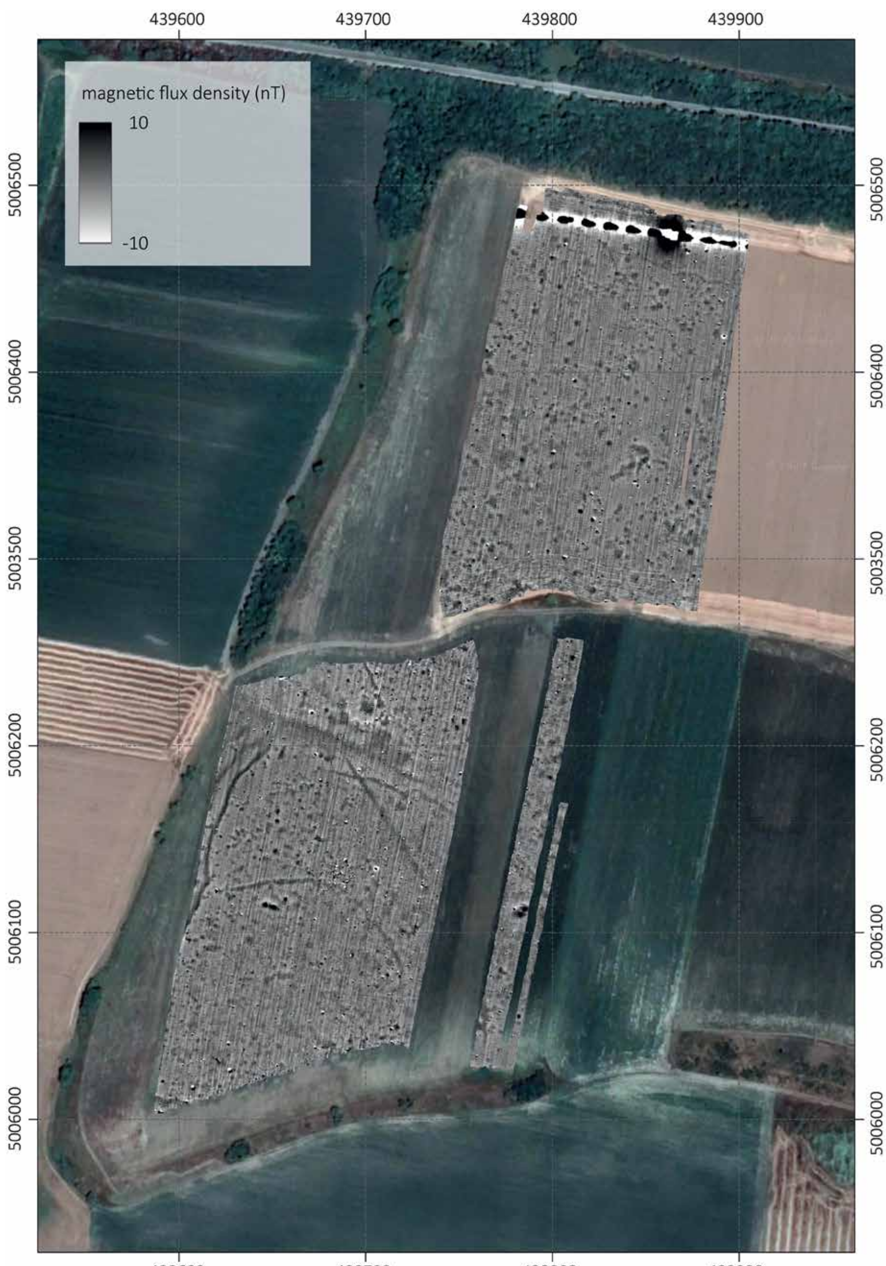


Figure 23. Plan of the archaeo-magnetic survey at Titel-Lok.

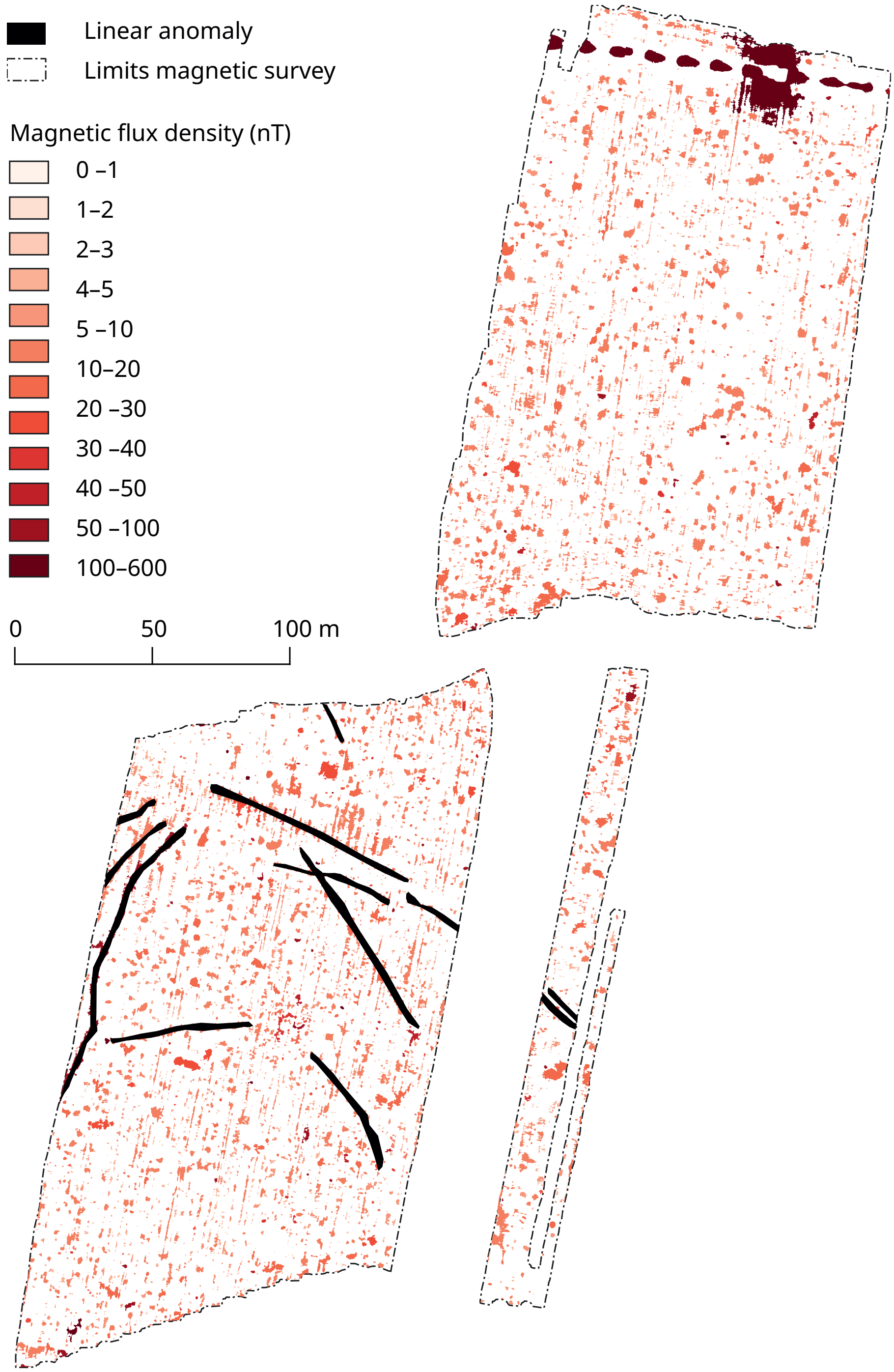


Figure 24. Interpretative plan of the archaeo-magnetic survey at Titel-Lok.

material was collected unsystematically during these campaigns. The magnetic image shows numerous anomalies of pits distributed relatively evenly over the entire prospected area. In the western area, the surface finds include concentrations of shells (Figs. 23 and 24). In the southern part of the magnetic plan linear anomalies are visible, two of them running close to each other in NW – SE direction. In the western part of the plan three parallel but curved lines are visible. The character of all of these linear anomalies is as yet unclear.

	Perlek	Makaranda	Taraš	Žabalj	Elemir	Aradac	Borđoš (tell)	Borđoš (flat settlement)
n	4	5	1	135	8	55	31	104
Minimum value (m²)	38.00	86.00	33.00	15.00	37.00	10.00	15.20	12.80
1st quartile	47.50	93.00	33.00	42.00	38.75	19.00	34.00	41.73
Median value	77.00	126.00	33.00	52.00	47.50	30.00	45.60	53.45
3rd quartile	102.75	157.50	33.00	65.00	58.00	40.00	56.10	74.90
Maximum value	111.00	183.00	33.00	118.00	62.00	53.00	84.10	121.00
Average/mean	75.75	125.40	33.00	54.43	48.63	29.98	44.82	56.90

Table 2. House sizes by site.

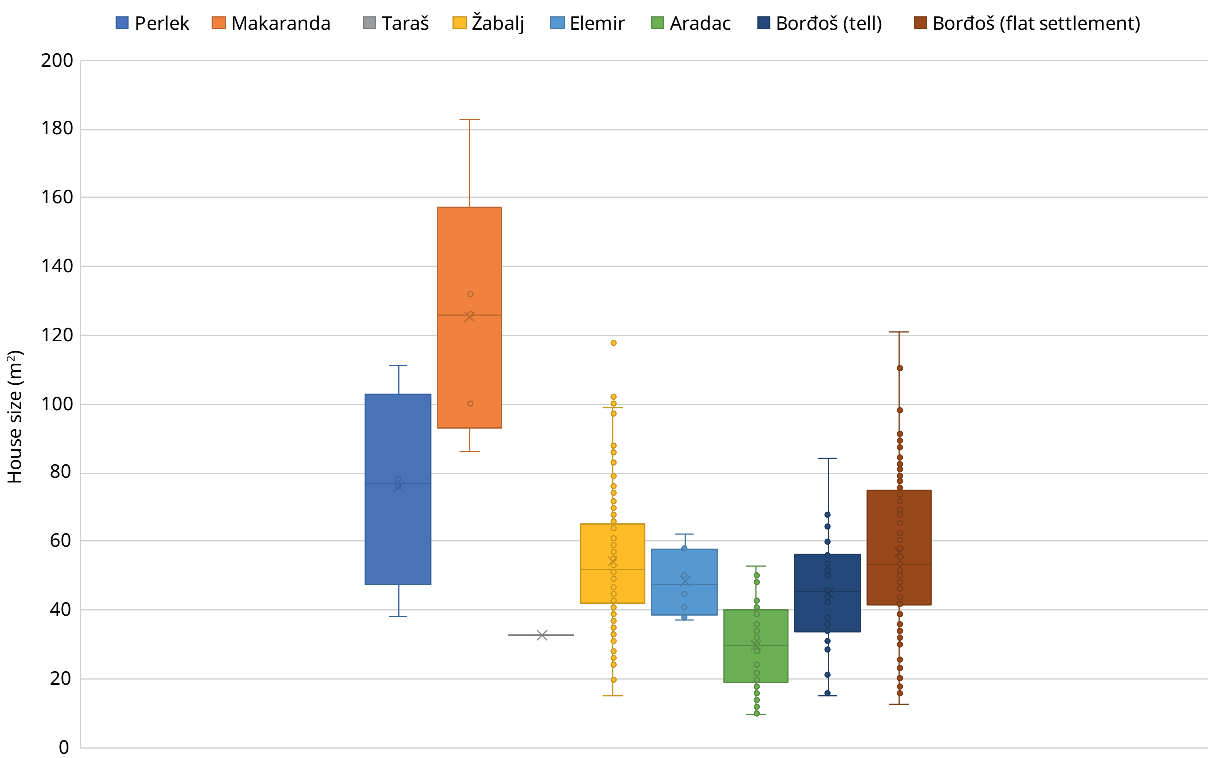


Figure 25. House sizes (m²) of the surveyed sites.

House sizes

We also present an overview of house sizes, based on the digitalised GIS plans we generated. We only took into account those houses that we had marked as definitely burnt (indicated with a solid line on all site maps in the paper). The evaluation of house sizes at Borđoš has already been published (Hofmann *et al.* 2019) (Table 2).

What stands out from the house size box-and-whisker plots in Fig. 25 is the extraordinarily large house sizes at Makaranda, which show a totally different range, *i.e.* the median of the house square metre is higher than all the other sites. Makaranda is an anomalous site in other respects too. It is the only site without a ditch clearly related to the houses; it has the least houses; and it shows no patterns of house placement, except for a similar orientation.

All the other sites cluster around house sizes of 40 to 60 m^2, except for Perlek, which includes some larger houses. But given the small number of houses identified in Perlek (n=4), that is not statistically different than, for example, the flat settlement at Borđoš. The house sizes at Aradac are clearly smaller in comparison to the other large sites Žabalj and Borđoš, and it is also obvious that at Borđoš, houses in the flat settlement are significantly larger and more variable than those on the tell.

Discussion

The settlement plans presented in this paper represent a range of examples of Early and Late Neolithic settlements on the lower course of the Tisza and provide new data for reconstructing the settlement size, population size and spatial organisation of prehistoric communities. They represent a valuable addition to already published settlement plans in the western Balkans and the Pannonian Plain (Mischka 2012; Müller *et al.* 2013; Crnobrnja 2014; Rassmann *et al.* 2015, 2021; Marić *et al.* 2016; Perić *et al.* 2016; Borić *et al.* 2018; Parkinson *et al.* 2018; Mesterházy *et al.* 2019; Becker and Schier 2020; Füzesi *et al.* 2020; Raczky *et al.* this volume) and can contribute to our possibilities for regionally differentiating among Neolithic settlement patterns.

The investigated settlements show enormous differences in size, ranging between 1 and 50 ha, and point to population aggregation processes as well as possible settlement hierarchies in the sense of different network centrality. Settlements with verified early dates, such as Novo Miloševo (Early and Late Neolithic) and Makaranda (early Late Neolithic) had, as far as can be determined, very moderate settlement sizes, in the range of 1-2 ha. In the later settlements, of the first half of the 5th millennium, that we focus on here, we observe an enormous variability in size, in which (in terms of rank-size distributions) sites such as Borđoš (50 ha), Žabalj (15 ha), and Opovo (10 ha) may have played a primate (central) role in terms of centrality in regional networks, compared with other settlements. Alongside such central places, smaller to medium-sized communities existed farther down the rank-size list, such as Aradac A (5 ha), Perlek (7 ha), and Taraš (2.2 ha), although it remains to be clarified to what extent these were in use simultaneously with the largest settlement (Fig. 26).

The settlement record in the study region is currently still incompletely researched, and regional settlement structures and processes can so far only be traced selectively for the Borđoš Late Pleistocene Terrace (Wilkes 2019) and the surroundings of the Titel Plateau (Falkenstein 1998). However, the described size differences and remarkable gaps in the distribution of sites (Marić and Mirković-Marić 2020) seem to indicate that similar regional settlement structures existed here in the Late Neolithic as are known from the Upper and Middle Tisza areas. There, within discrete settlement clusters, some large 'supersites' functioned as regional centres and focuses of population aggregation (Parkinson 2006; Raczky and Füzesi 2016). This preliminary interpretation needs to be verified in the future by densifying the regional data set available to us and by clarifying individual settlement biographies.

An extremely important finding of our investigations is that in many cases larger sites, similar to what we see with ancient, medieval and modern towns, had a longer history, corresponding to a non-uniform structure of settlement plans, with several 'components' and differing thicknesses of anthropogenic deposits. In our study region, this has so far been best observed at Borđoš, where in addition to a tell settlement that accumulated over about 400 years, there existed an extensive flat settlement for about 200 years (Hofmann *et al.* 2019). Together, these settlement components form a twin settlement, which is only little integrated in terms of settlement plan. Similar twin and triple structures are known from the

Figure 26. Plans of the layouts of the surveyed settlements.

LBK settlement of Vráble (Furholt *et al.* 2020), from Late Neolithic settlements in Slavonia (Kalafatić and Šiljeg 2018), and from Copper Age settlements in eastern Europe (Ţerna *et al.* 2021; Rud *et al.* in press).

Among the sites along the lower reaches of the Tisza presented in this paper, a comparable situation of twin settlements is possibly found in the two spatially separated settlement areas at the site of Aradac, although the contemporaneity of the two spatially separated ditch systems (A and B) has not yet been confirmed. The other settlement plans presented in this paper show a single-component structure, representing either flat settlements (Elemir, Taraš, Perlek, Novo Miloševo, Makaranda) or tell-like settlements (Žabalj, Opovo), probably depending on the duration of habitation.

With the exception of Makaranda, Titel-Lok, Novo Miloševo and Borđoš D, all the settlements studied are enclosed by ditches, most of which show circular layouts. This round shape distinguishes the plans from the mostly tendentially

rectangular settlement plans in the mountainous zone of the western Balkans (Müller *et al.* 2013; Crnobrnja 2014; Borić *et al.* 2018; Rassmann *et al.* 2021).

Based on the archaeo-magnetic survey, we can distinguish different types of ditch systems: The settlement area of Elemir was enclosed by a single ditch. On the tell of Borđoš and at Žabalj and Aradac B, there existed double ditch systems, which do not overlap each other and whose temporal relationship is thus unclear. In contrast, in the flat settlement at Borđoš and at Aradac A, multiple ditches are visible, some of which are overlapping. This indicates repeated re-cuttings and re-fillings, similar to what has been found, for example, at Okolište, in central Bosnia (Müller *et al.* 2013, 111-115). The ditches in the flat settlement at Borđoš and at Aradac A partly followed the same course and partly can be understood as adaptations to a change in settlement size. In the case of the rondel at Borđoš (C), it could be stratigraphically proven that two ditches were standing open simultaneously (Hofmann, Medović *et al.* this volume). At the entrance visible in the magnetic plan, the two ditches are interconnected by a radially running ditch, and in this respect these ditches show similarities with those at many of the roughly contemporaneous Neolithic rondels (mainly distributed in the western part of the Pannonian Plain and farther to the north and west – see Řídký *et al.* 2019). The presence of such connecting ditches at Taraš and Perlek indicates that several ditches could also have been used simultaneously. Since, on the other hand, these settlements also contain buildings inside the enclosed area, this shows that the boundaries between the categories of rondel and settlement are fuzzy here.

As far as can be determined, the arrangement of archaeo-magnetically visible (burnt) houses follows two fundamentally different principles. At Aradac, the houses are mostly oriented NE – SW and tend to be arranged in rows. In contrast, at Borđoš, Žabalj and Perlek, the houses are oriented with their longitudinal axis towards the centre of the settlement. At Borđoš, the distribution of finds indicates that there was an undeveloped area in the centre of the settlement, which we regard as a possible place for making decisions concerning the village community and for integrative activities, such as festivals. We therefore call this arrangement 'centripetal'. With regard to this interpretation, however, it must be critically noted that this possible central square was not clearly demarcated from the house area and was not architecturally emphasised by any building line. This distinguishes the situation at Borđoš from, for example, the central and also the secondary plazas in eastern European Trypillia settlements (Hofmann *et al.* in press).

The situation in the centre of the other settlements examined by us is just as unclear as that at Borđoš. At Aradac, Elemir, Perlek and Taraš, there is no evidence for the existence of a public square. The existence of a central plaza at Žabalj is even more likely to be disputed, since the area built up with houses stretched practically to the centre of the settlement, where a smaller ditch system was also located. However, it cannot be ruled out that other, larger, unbuilt areas within the settlement were used for public meetings and action. In summary, it can be stated that the evidence for public spaces in almost all of the settlements examined is dubious at best, while there are a few arguments for a public space in the case of Borđoš.

If we look at the spatial distribution of the different principles of settlement organisation from a large-scale perspective, it becomes clear that our investigation region represents a border situation. Žabalj represents the southernmost known settlement with a centripetal layout, which is also found at Szegvár-Tűzköves (Csongrád-Csanád county, Hungary) and Iclod (Judetul Cluj, Romania) (Mischka 2012; Raczky *et al.* this volume). South of Žabalj, 'row-shaped' layouts (in the broadest sense of the word) with uni- or bimodally oriented

houses can be found in the entire Balkan region. The row-like arrangement of their houses is partly responsible for the often-rectangular structure of these settlements, while ‘centripetal’ arrangements often occur in settlements with circular settlement plans.

It should be emphasised that in the eastern part of the Alföld, in addition to ‘centripetal’ layouts, often occur arrangements with uni- and bimodally oriented houses. In our study area, this concerns Aradac and Iđoš-Gradište, and on the middle reaches of the Tisza this concerns *e.g.* Polgár-Csőszhalom and Szeghalom-Kovácshalom (Parkinson *et al.* 2018; Mesterházy *et al.* 2019). An open question so far is which criteria were used to decide on the layout of the settlement. Do centripetal layouts reflect a trend associated with a particular social organisation in the first half of the 5th millennium, in contrast to earlier, row arrangements? Or are we dealing with regional variation in cultural preferences, without many real-life social consequences?

In the anthropological literature, circular arrangements of settlements are often associated with an egalitarian ethos (Wagner 2019; Graeber and Wengrow 2021, 304), as such a layout may give fewer opportunities for differences among houses when it comes to position within the site. Like a ‘round table’, such a settlement plan is at times reported to have been intentionally created with equality of the participating community in mind (Ott 1981; Ascher 2004; Wagner 2019). At least in situations in which the centre of the site, towards which houses in a centripetal layout are oriented, is unoccupied or used for communal activities, one could plausibly argue that this would pragmatically create an arena for social encounters which would at least not foster inequality and would thus support an existing egalitarian ethos. To prove or disprove whether this actually is the case would require a systematic comparison of indicators for social inequality and their association with settlement layout on a larger scale, which is beyond the scope of this paper.

Conclusion

Geographically, the region along the lower course of the Tisza is characterised by very fertile loess soils, the confluence of important rivers and the transition between the Pannonian Plain and the low mountain range of the western Balkan region. This location at the interface of different ecological zones and natural communication routes resulted in an increased cultural diversity already during the Neolithic, reflected in the high diversity of pottery styles. Based on nine newly obtained magnetic settlement plans, we investigate in this paper to what extent this increased plurality can also be traced on the basis of settlement patterns and we investigate which settlement processes took place here in the Neolithic. During the Late Neolithic, enormous differences in the size of settlements indicate intensive population aggregation processes, which in some cases led to the formation of regional centres for larger catchment areas. Settlements of this scale are characterised by very different biographies and degrees of integration of tells, flat settlements and circular ditches into single- or multicomponent settlement layouts. The majority of the investigated settlements were surrounded by different types of ditch systems and were characterised by orthogonal or centripetal arrangements of houses. These features testify both to the high diversity in settlement forms in the study region and to their integration into differently directed networks, towards the Pannonian Plain on the one hand and the Balkans on the other.

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References

Ascher, M., 2004. *Mathematics elsewhere: an exploration of ideas across cultures*. Princeton, NJ: Princeton University Press.

Autenrieth, S., 2015. *Die spätneolithische Siedlung Borđoš, Vojvodina: interregionale Beziehungen und interne Differenzierung*. Unpublished master's thesis. Kiel University, Kiel.

Bartos-Elekes, Z., 2016. *Az 1910-es Magyarország demográfiai térképsorozatainak georeferálása* és *webes közzététele*. Budapest: Arcanum Adatbázis Kft.

Becker, H. and Schier, W., 2020. Magnetikprospektion / Geophysical prospection. *In:* W. Schier and F. Draşovean, eds. *Uivar 'Gomilă': a prehistoric tell settlement in the Romanian Banat*. Vol. 1. *Site, Architecture, Stratigraphy and Dating*. Rahden: Verlag Marie Leidorf, 54-62.

Bede, Á., 2016. *Kurgánok a Körös – Maros vidékén… Kunhalmok tájrégészeti* és *tájökológiai vizsgálata a Tiszántúl középső részén [Kurgans in the land of the Körös and Maros rivers… Landscape archaeological and landscape ecological investigations on mounds in the central part of the Tiszántúl region, Hungary]*. Budapest: Magyar Természettudományi Társulat.

Biszak, S., Timár, G., Molnár, G., Jankó, A., 2007 a. *Digitized maps of the Habsburg Empire – The Third military survey, Ungarn, Siebenbürgen, Kroatien-Slawonien, 1867-1887, 1:25000*. Budapest: Arcanum Adatbázis Kft.

Biszak, S., Timár, G., Molnár, G., Jankó, A., 2007b. *Digitalised First military survey maps of the Habsburg Empire (1763-1790)*. Budapest: Arcanum Adatbázis Kft.

Borić, D., Hanks, B., Šljivar, D., Kočić, M., Bulatović, J., Griffiths, S., Doonan, R., Jacanović, D., 2018. Enclosing the Neolithic world: a Vinča culture enclosed and fortified settlement in the Balkans. *Current Anthropology*, 59 (3), 336-346.

Chapman, J., 2020. *Forging identities in the prehistory of Old Europe: dividuals, individuals and communities, 7000-3000 BC*. Leiden: Sidestone Press.

Chapman, J.C., 1981. *The Vinča culture of south-east Europe: studies in chronology, economy and society*. Oxford: British Archaeological Reports.

Crnobrnja, A.N., 2014. The (E)neolithic settlement Crkvine at Stubline, Serbia. *In:* W. Schier and F. Draşovean, eds. *The Neolithic and Eneolithic in southeast Europe: new approaches to dating and cultural dynamics in the 6th to 4th millennium B.C.* Rahden: Verlag Marie Leidorf GmbH, 173-186.

Falkenstein, F., 1998. *Feudvar: 2. Ausgrabungen und Forschungen in einer Mikroregion am Zusammenfluss von Donau und Theiss. 2. Die Siedlungsgeschichte des Titeler Plateaus*. Kiel: Oetker-Voges Verlag.

Furholt, M., Müller-Scheeßel, N., Wunderlich, M., Cheben, I., Müller, J., 2020. Communality and discord in an Early Neolithic settlement agglomeration: the LBK site of Vráble, southwest Slovakia. *Cambridge Archaeological Journal*, 30 (3), 469-489.

Füzesi, A., Rassmann, K., Bánffy, E., Raczky, P., 2020. Human activities on a Late Neolithic tell-like settlement complex of the Hungarian Plain (Öcsöd-Kováshalom). *In:* A. Blanco-González and T.L. Kienlin, eds. *Current approaches to tells in the prehistoric Old World*. Oxford and Philadelphia: Oxbow Books, 139-162.

Graeber, D. and Wengrow, D., 2021. *The dawn of everything: a new history of humanity*. Great Britain: Penguin.

Hofmann, R., Medović, A., Furholt, M., Medović, I., Pešterac, T.S., Dreibrodt, S., Martini, S., Hofmann, A., 2019. Late Neolithic multicomponent sites of the Tisza region and the emergence of centripetal settlement layouts. *Praehistorische Zeitschrift*, 94 (2), 351-378.

Hofmann, R., Shatilo, L., Rassmann, K., Rud, V., Ţerna, S., Dreibrodt, S., Chabanyuk, V., Kirleis, W., Müller, J., in press. Ring-shaped settlement plans and Tripolye population agglomeration. *In:* R. Hofmann, W. Kirleis, J. Müller, V. Rud, S. Ţerna†, M. Videiko, eds. *From Ros to Prut: transformations of Tripolye settlements. Volume II*. Leiden: Sidestone Press.

Hofmann, R., Ţerna, S., Ursu, C.-E., Brandtstätter, L., Tiede, H., Mainusch, W., Autenrieth, S., 2016. Spatial organization and population size of small Cucuteni-Tripolye settlements: results of geomagnetic surveys in Baia and Adâncata, Suceava County, Bucovina, eastern Romania. *Journal of Neolithic Archaeology*, 18, 157-189.

Kalafatić, H. and Šiljeg, B., 2018. Krugovi Parnjaci: novi uvidi u neolitičke obrasce naseljavanja. *Prilozi Instituta za Arheologiju u Zagrebu*, 35, 71-109.

Link, T., 2006. *Das Ende der neolithischen Tellsiedlungen: ein kulturgeschichtliches Phänomen des 5. Jahrtausends v. Chr. im Karpatenbecken*. Bonn: Dr. Rudolf Habelt GmbH.

Marić, M. and Mirković-Marić, N., 2020. The Tisza divide: the missing Late Neolithic transformation in the north Bačka region of Serbia. *Quaternary International*, 560-561, 78-85.

Marić, M., Mirković-Marić, N., Molloy, B., Jovanović, D., Martl, P., Milašinivic, L., Pendić, J., 2016. New results of the archaeological excavations on the site Gradište near Iđoš: season 2014. *Glasnik Srpskog arheološkog društva*, 32, 125-152.

Marković, S.B., McCoy, W.D., Oches, E.A., Savić, S., Gaudenyi, T., Jovanović, M., Stevens, T., Walther, R., Ivanišević, P., 2005. Paleoclimate record in the Upper Pleistocene loess-paleosol sequence at Petrovaradin brickyard (Vojvodina, Serbia). *Geologica Carpathica*, 56 (6), 545-552.

Martini, S.J., 2019. *On-site geoarchaeology as a method of archaeological hypothesis testing on multilayered settlement mounds – An investigation of epistemological possibilities and their limitations*. Unpublished master's thesis. Kiel University, Kiel.

Medović, A., Hofmann, R., Stanković-Pešterac, T., Dreibrodt, S., Medović, I., Pešterac, R., 2014. The Late Neolithic settlement mound Borđoš near Novi Bečej, Serbian Banat, in a multiregional context – preliminary results of geophysical, geoarchaeological and archaeological research. Рад Музеја Војводине, 56, 53-77.

Medović, P., 1998. Die Geländebegehungen im Raum um das Titeler Plateau 1965 und 1969. *In:* B. Hänsel and P. Medović, eds. *Feudvar: Ausgrabungen und Forschungen in einer Mikroregion am Zusammenfluss von Donau und Theiss*. Kiel: Oetker-Voges Verlag, 41-140.

Mesterházy G., Serlegi G., Vágvölgyi B., Füzesi A., Raczky P., 2019. A szociális folyamatok színterei Polgár-Csőszhalom késő neolitikus településének összefüggéseiben

[Arenas of Social Dynamics on the Late Neolithic settlement of Polgár-Csőszhalom]. *Archaeologiai* Értesítő, 144 (1), 1-32.
Mirković-Marić, N. and Marić, M., 2017. Late Neolithic Tisza sites in the Serbian part of Banat. *Archaeologiai* Értesítő, 142 (1), 1-34.
Mischka, C., 2012. Late Neolithic multiphased settlements in southern Transilvania: a geophysical survey and test excavation. *In:* R. Hofmann, F.-K. Moetz, J. Müller, eds. *Tells: social and environmental space. Proceedings of the international workshop 'Socio-Environmental Dynamics over the last 12.000 years: the creation of landscapes II (14th-18th March 2011)' in Kiel*. Bonn: Dr. Rudolf Habelt GmbH, 153-166.
Müller, J., Rassmann, K., Kujundžić-Vejzagić, Z., 2013. Okolište – Rekonstruktion spätneolithischer und frühchalkolithischer Siedlungsprozesse des zentralbosnischen Visokobeckens: Fragestellungen, Forschungsstrategien, Ergebnisse. *In:* J. Müller, K. Rassmann, R. Hofmann, eds. *Okolište 1: Untersuchungen einer spätneolithischen Siedlungskammer in Zentralbosnien*. Bonn: Dr. Rudolf Habelt GmbH, 11-68.
Müller-Scheeßel, N., Müller, J., Cheben, I., Mainusch, W., Rassmann, K., Rabbel, W., Corradini, E., Furholt, M., 2020. A new approach to the temporal significance of house orientations in European Early Neolithic settlements. *PLoS One*, 15 (1), e0226082.
Ott, S., 1981. *The Circle of Mountains: a Basque shepherding community*. Oxford: Clarendon Press.
Parkinson, W.A., 2006. Tribal boundaries: stylistic variability and social boundary maintenance during the transition to the Copper Age on the Great Hungarian Plain. *Journal of Anthropological Archaeology*, 25 (1), 33-58.
Parkinson, W.A., Gyucha, A., Karkanas, P., Papadopoulos, N., Tsartsidou, G., Sarris, A., Duffy, P.R., Yerkes, R.W., 2018. A landscape of tells: geophysics and microstratigraphy at two Neolithic tell sites on the Great Hungarian Plain. *Journal of Archaeological Science: Reports*, 19, 903-924.
Perić, S., Rummel, C., Schäferer, G., Winger, D., Wendling, H., 2016. Geomagnetic survey of Neolithic settlements in the Middle Morava Valley – preliminary results. *In:* S. Perić, ed. *The Neolithic in the Middle Morava Valley: new insights into settlements and economy*. Belgrade: Institute of Archaeology, Belgrade, Regional Museum, Paraćin, 9-28.
Przybyłar, M.M. and Podsiadło, M., 2021. Magnetic prospection on Yamnaya culture burial mounds in Bačka. *In:* P. Jarosz, J. Koledin, P. Włodarczak, eds. *Danubian route of the Yamnaya culture: the barrows of Vojvodina*. Budapest: Archaeolingua Alapítvány, 29-46.
Raczky, P. and Füzesi, A., 2016. Öcsöd-Kováshalom: a retrospective look at the interpretations of a Late Neolithic site. *Dissertationes Archeologicae*, 3 (4), 9-42.
Rassmann, K., Furholt, M., Müller-Scheeßel, N., Müller, J., 2021. The social organisation of the Vinča culture settlements: new evidence from magnetic and archaeological excavation data. *In:* M. Radivojević, B. Roberts, M. Marić, J. Kuzmanović-Cvetković, T. Rehren, eds. *The rise of metallurgy in Eurasia: evolution, organisation and consumption of early metal in the Balkans*. Oxford: Archaeopress Archaeology, 455-459.
Rassmann, K., Mischka, C., Furholt, M., Ohlrau, R., Radloff, K., Winkelmann, K.H., Serlegi, G., Marton, T., Osztás, A., Oross, K., Bánffy, E., 2015. Large scale geomagnetic prospection on Neolithic sites in Hungary. Part 2. *Hungarian Archaeology E-Journal*, (summer), 1-6.
Řídký, J., Květina, P., Limburský, P., Končelová, M., Burgert, P., Šumberová, R., 2019. *Big men or chiefs? Rondel builders of Neolithic Europe*. Oxford: Oxbow Books.
Rud, V., Hofmann, R., Kosakivskyi, V., Zaitseva, V., Shelehan, O., Salefski, G., Müller, J., Hofmann, R., Kirleis, W., Müller, J., Rud, V., Ţerna, S., Videiko, M., in press. Ring-shaped settlement plans and Tripolye population agglomeration. *In:* R. Hofmann, W. Kirleis, J. Müller, V. Rud, S. Ţerna†, M. Videiko, *From Ros to Prut: transformations of Tripolye settlements*. Volume II. Leiden: Sidestone Press.

Stanković Pešterac, T., Hofmann, R., Medović, A., Dreibrodt, S., Medović, I., 2014. Multidisciplinary archaeological research at the Late Neolithic site Borđoš (Borjas) near Novi Bečej (northern Serbia): geoelectrical prospection of a house. *In:* Sorin Forţiu, Adrian Cîntar, *Arheovest. 2: In honorem Prof. Univ. Dr. Gheorghe Lazarovici: Interdisciplinaritate* în *Arheologie: Timişoara, 6 decembrie 2014*. Szeged: JatePress Kiadó.

Ţerna, S., Vornicu-Ţerna, A., Diachenko, A., Harper, s., Rassamakin, J.Ja., Sobkowiak-Tabaka, I., 2021. The potential of Google Earth spatial imagery for detecting Cucuteni-Tripolye settlements: some examples from an ongoing investigation (Republic of Moldova and northeastern Romania). *In:* Diachenko, A., Harper, T. K., Rassamakin Yu., Sobkowiak-Tabaka I., *Data systematization in the Neo-Eneolithic of south-eastern and central Europe: essays in honor of Sergej Ryzhov*. Kyiv: Institute of Archaeology of the National Academy of Sciences of Ukraine, 265-305.

Timár, G., Biszak, S., Székely, B., Molnár, G., 2010. Digitized maps of the Habsburg Military Surveys – Overview of the project of ARCANUM Ltd. (Hungary). *In:* M. Jobst, ed. *Preservation in digital cartography: archiving aspects*. Berlin and Heidelberg: Springer, 273-283.

Timár, G., Molnár, G., Lévai, P., Varga, J., 2004. A második világháború német katonai térképeinek koordinátarendszere [GIS integration of the German Army Grid (DHG) and its geodetic datums]. *Geodézia és Kartográfia* 56/6, 28-35.

Timár, G., Molnár, G., Székely, B., Biszak, S., Varga, J., Jankó, A., 2006. *Digitized maps of the Habsburg Empire – The map sheets of the second military survey and their georeferenced version.*

Tringham, R., Brukner, B., Kaiser, T., Borojević, K., Bukvić, L., Šteli, P., Russell, N., Stevanović, M., and Voytek, B., 1992. Excavations at Opovo, 1985-1987: Socioeconomic Change in the Balkan Neolithic. Journal of Field Archaeology, 19 (3), 351–386.

Tringham, R., Brukner, B., and Voytek, B., 1985. The Opovo Project: a Study of Socioeconomic Change in the Balkan Neolithic. Journal of Field Archaeology, 12 (4), 425–444.

Vilotijević, D., 1965. Nove zemlje, Žabalj – višeslojno praistorijsko nalazište. *Arheološki pregled*, 7, 31-32.

Wagner, T., 2019. An-Architektur: politische Aspekte der Siedlungsformen primitiver Gesellschaften. *In:* R. Haude and T. Wagner, eds. *Herrschaftsfreie Institutionen: Texte zur Stabilisierung staatsloser, egalitärer Gesellschaften*. Heidelberg: Verlag Graswurzelrevolution, 105-135.

Wilkes, F., 2019. *Settlement and landscape development of the Borđoš plateau, Serbia.* Unpublished master's thesis. Kiel University, Kiel.

Włodarczak, P., 2021. Investigations of prehistoric barrows in Bačka – Introduction. *In:* P. Jarosz, J. Koledin, P. Włodarczak, *Danubian route of the Yamnaya culture: the barrows of Vojvodina*. Budapest: Archaeolingua Alapítvány, 9-28.

Wunderlich, T., Kahn, R., Nowaczyk, N.R., Pickartz, N., Schulte-Kortnack, D., Hofmann, R., Rabbel, W., 2022. On-site non-destructive determination of the remanent magnetization of archaeological finds using field magnetometers. *Archaeological Prospection*, 29 (2), 205-227.

Бењоцки, Н., 2018. Археолошки локалитети Зрењанинског подручја. Зрењанин: Завод за заштиту споменика културе.

Рамадански, Р., Трипковић, Ј., Шаркић, Н., Мирковић-Марић, Н., 2022. Вишеслојни археолошки локалитет Перлек – Оранице Беркеша код Бечеја [The multilayered archaeological site of Perlek – Oranice Berkeša near Bečej]. Рад музеја Војводине, (64), 7-27.

Szegvár-Tűzköves (Tisza region, Hungary): Teaching an old site new tricks

Pál Raczky, András Füzesi, Gábor Mesterházy, Kata Furholt, Eszter Bánffy, Knut Rassmann, Máté Stibrányi, Gábor Serlegi

Abstract

The site of Szegvár is one of the key Late Neolithic (Tisza culture) stratified settlements of the early 5th millennium BCE on the Great Hungarian Plain. In the wake of new archaeological research, it proved possible to reveal previously unknown dimensions of the Late Neolithic settlement and to refute some of the previously uncontested assumptions related to the site. The magnetic anomalies recorded during the new geomagnetic survey reveal an enclosure system of multiple ditches ringing the settlement, which extended over an area of roughly 32 ha. The 1.8-2 ha tell-like main habitation area, which lay in the settlement's western part, has suffered extensive damage. The settlement mound and the houses upon it, which were oriented towards a focal area, formed a distinctive monumental spatial system on the southern portion of the Great Hungarian Plain in the early 5th millennium BCE.

Keywords: *Great Hungarian Plain, Late Neolithic, Tisza culture, magnetic prospection, settlement archaeology, tell, enclosure, house burning*

Earlier research at Szegvár-Tűzköves

The site of Szegvár-Tűzköves is located on the shore of former Lake Kontra, the fully drained remnant of a Pleistocene riverbed east of the River Tisza. Lying in an area north of the confluence with the River Maros, it is one of the key Late Neolithic stratified settlements of the early 5th millennium BCE, together with Öcsöd-Kováshalom, Hódmezővásárhely-Kökénydomb, Hódmezővásárhely-Gorzsa and Tápé-Lebő, which lie along the southern part of the River Tisza (Fig. 1) (Kalicz and Raczky 1990, 8-9; Link 2006, Fig. 9; Raczky *et al.* 2021, Fig. 1). Some of these sites, such as Tápé-Lebő (Horváth 1994, 25-28; Kalicz 2013) and Hódmezővásárhely-

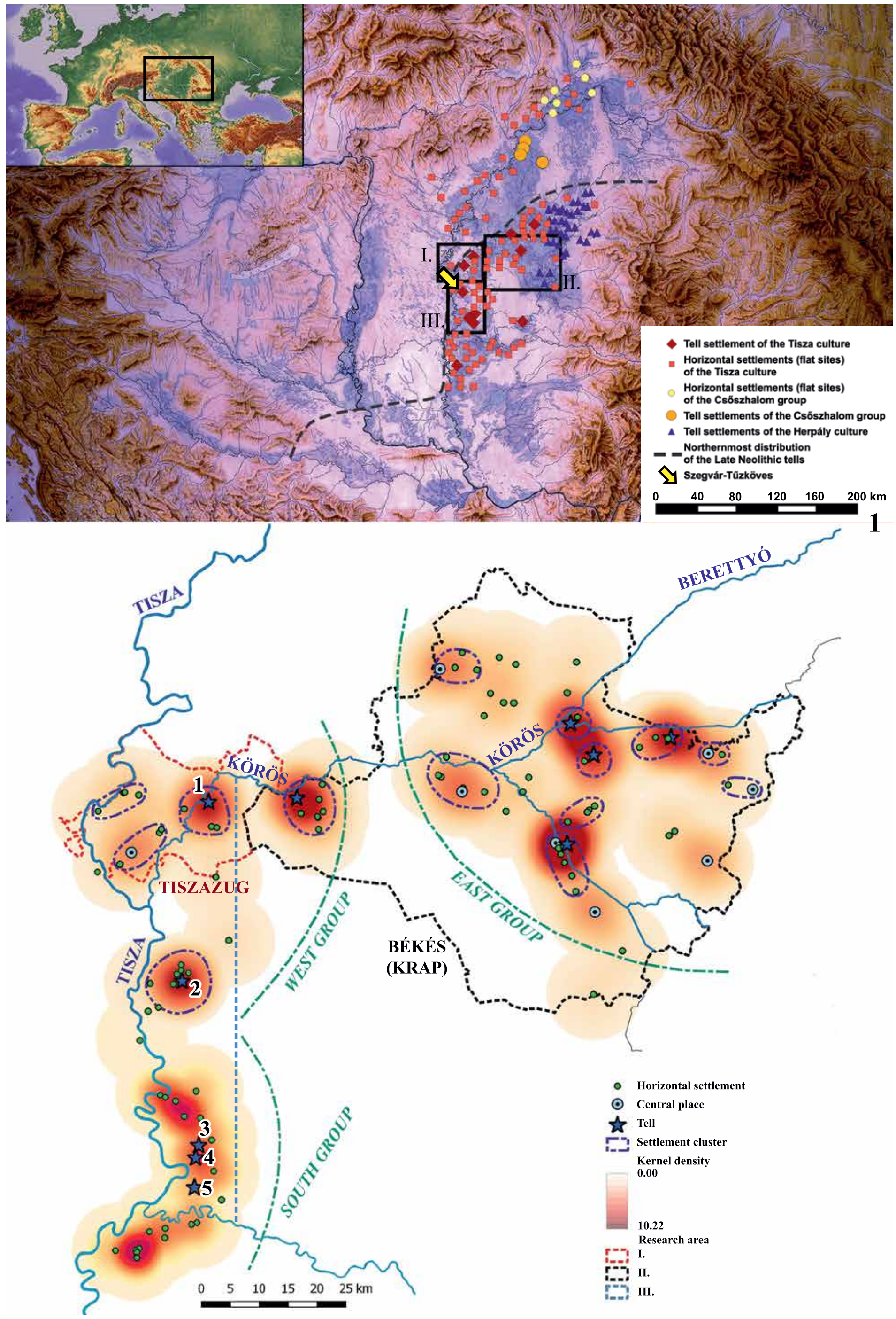

Figure 1. Maps showing the Late Neolithic sites on the Great Hungarian Plain. 1. Map showing the northern boundary of the distribution of stratified mounds and the research areas of the major regional research projects. I Tiszazug Micro-regional Project; II Körös Regional Archaeological Project; III Late Neolithic Tells in the Lower Tisza Region Project. 2. Distribution of the Late Neolithic settlement clusters in the Körös and Lower Tisza regions, showing the regional units and sites mentioned in the text. 1. Öcsöd-Kováshalom; 2. Szegvár-Tűzköves; 3. Hódmezővásárhely-Kökénydomb; 4. Hódmezővásárhely-Gorzsa; 5. Tápé-Lebő (after Füzesi et al. 2020, Fig. 10.1).

Kökénydomb (Banner 1930, 1951; Banner and Foltiny 1945; Banner and Korek 1949), gained archaeological prominence in the early twentieth century, following their excavation and the findings thereof, which were complemented by the investigation of the Csóka-Kremenyák (Serbian: Čoka-Kremenjak, in the Serbian Banat) site, south of the River Maros (Móra 1925; Banner 1960). Lying in the Banat subregion, Csóka was one of the most important links to the Vinča tell, which, following V. Gordon Childe's lead, was regarded as the universal yardstick of south-east European prehistoric studies from the early twentieth century (Childe 1929, 27, Fig. 9; cf. also Chapman 2009, 148-149). One scholarly consensus emerging from the

heated debates about this period, based principally on Ferenc Tompa's views, was that the Neolithic tells on the southern portion of the Great Hungarian Plain and the Tisza culture should be pegged to cultural developments in the Balkans (Tompa 1937, 41-42; Milojčić 1949, 92; Garašanin 1951; Schachermeyr 1952-53).

The long-term archaeological investigation of the intensely occupied settlement of Szegvár-Tűzköves began after the Second World War, on the initiative of Júlia Kovalovszky and József Csalog. The excavations by József Csalog (1955-1964), József Korek (1970), Katalin Hegedűs (1978) and Ferenc Horváth (1986), whose activities represent the main milestones in the settlement's exploration, yielded a wealth of unusual and remarkable finds (Korek 1990; Horváth 2004; Rezi-Kató 2009; Seleanu 2014).

In line with the scholarly interests of the period, the unique and aesthetically pleasing human figurines and face pots (Figs. 2 and 3) garnered far greater scholarly interest than the rest of the archaeological assemblages brought to light during the first campaigns in the 1950s and 1960s. Szegvár-Tűzköves became known as the findspot of unique figurines, even though they lacked a proper archaeological context. There was exceptional interest in the figurine dubbed the Sickle God (Csalog 1956, Fig. 1a, 1957, Fig. 1, 1959, 24-26, Figs. 7-10, 1960a, 2, Pl. XXXI) (Fig. 2.1): the figurine, portraying a seated male figure holding a sickle over his shoulder, appeared in almost every overview and handbook on European prehistory (*e.g.* Makkay 1964, Pl. 1; Piggott 1965, Fig. 19; Höckmann 1968, Figs. 4-6; Müller-Karpe 1968, II, Table 187, A1; Kalicz 1970, Figs. 32-34; Tringham 1971, Pl. 7; Gimbutas 1974, Pls. 46-47; Hansen 2007, Fig. 92; Bánffy 2017, Fig. 31.6), while the implement itself became the subject of heated debates in Hungarian scholarship. The question whether it was indeed a harvesting tool or, instead, a sickle-shaped weapon (German: *Krummschwert*) also involved issues of chronology and the relevance of archaeological analogies from other cultural contexts (for overviews, cf. Csalog 1960b; Makkay 1964, 48-57). Yet, the only thing known about its find context is that it was found broken into several pieces somewhere in the middle of Trench V, at a depth of 125 cm, among the debris of a burnt house, in autumn 1956 (Csalog 1959, 24; Seleanu 2014, 9, and note 4). Neither then, nor later was any information available on which excavated house was meant by Csalog. A few years later, in a study discussing the ornamentation of pottery from Hódmezővásárhely-Kökénydomb, Csalog published a plan of Trenches II, V and VII at the site, which showed the remains of House C and six crouched burials but made no mention of the Sickle God figurine (Csalog 1966, Fig. 6).

In sum, the information on the investigation of the Szegvár settlement – particularly on the location of the excavations and the archaeological contexts – published at the time is patchy, to say the least. The first site plan showing the location of all excavation trenches, including the ones opened by Csalog, was prepared by Korek, who continued the investigation of the site in 1970. This site plan first appeared in 1973 and was then made accessible to archaeological scholars in 1987 and 1990 (Korek 1973, Fig. 4, 1987, 48 Fig. 1, 1990, Fig. 55; Link 2006, Fig. 48).

Korek wrote a comprehensive overview of the most remarkable finds from the Szegvár-Tűzköves site and a summary of earlier investigations for the catalogue accompanying the exhibition showcasing the Late Neolithic of the Tisza region organised in 1987 (Korek 1987). The exhibition travelled to Germany and France in 1990 and 1991, together with the German and French version of the catalogue containing a detailed description of the exhibited items (Kalicz *et al.* 1990, cat. nos 20-42, 134-152, 208, 249, 347, 355, 356; Korek 1990). The catalogues included the most recently found seated figurine, holding a clay axe, discovered in the wall of a pit silo in 1989 (Fig. 2.5) (Trogmayer 1990, 1991). For the first time in the history of research into the Szegvár site, the earlier, fragmentary view offered by the preliminary reports and interim studies was replaced by a broader interpretative picture for the international archaeological community (Link 2006, 114-116), a major milestone at the time.

Figure 2 (top row). Enthroned human figurines from Szegvár-Tűzköves (Tisza region, Hungary) (height 25.6 cm, 21.7 cm, 19.5 cm, 16.5 cm, 24.6 cm, from left to right) (photos: Károly Kozma).

Figure 3 (bottom row). Face pots with incised decoration from Szegvár-Tűzköves (Tisza region, Hungary) (height 16.5 cm, 21.6 cm, 16.1 cm, from left to right) (photo: Károly Kozma).

Yet while the publication of a site plan for the Szegvár-Tűzköves settlement was a significant step forward, the site documentation pales in comparison with the field documentation of Hódmezővásárhely-Kökénydomb, the other prominent site of the Classic Tisza culture. János Banner's five reports on his excavations of the settlement, conducted between 1929 and 1944, all contained site plans documenting the features excavated during a particular campaign, alongside excavation photos showing the notable finds, such as the hollow female figurines, in their original contexts (Banner and Korek 1949, Fig. 5, Pls. 5.1-4 and 10.7-8). In contrast, nothing can be gleaned from the site plan of Szegvár-Tűzköves, not even the exact location of the excavated features, particularly of the houses and burials, or their stratigraphic context or position relative to other features. The first attempt to clarify the stratigraphy of the site can be found in Magdaléna Seleanu's master's thesis, based on the field observations made during Katalin Hegedűs's 1978 excavation and the information on the earlier excavation trenches and the depth data of the houses and burials recorded in the field diaries and scattered throughout various publications (an edited, digital version of the master-thesis submitted in 1981 appeared online in 2014; Seleanu 2014, Table 13). In 1986, Horváth opened a small trench in an undisturbed part of the settlement's lakefront area (Trench XXVI, 5 × 5 m) to clarify the stratigraphic sequence. He distinguished 29 levels in the 4 m deep deposit, 22 of which he assigned to the Tisza culture. According to his brief report, the lowermost 1-1.4 m thick deposit could be assigned to the early Tisza culture, while the superimposed 1.5 m thick deposit represented the Classic Tisza period (Horváth 2004, 8, 11-12). At the time, however, there was no way of determining whether this sequence could be extrapolated to the entire settlement.

Szegvár-Tűzköves is not just a famous, but also an infamous site in Hungarian archaeology, because despite the fact that excavations had conducted, and despite the fact that it had been afforded local and national protected heritage status, it proved impossible to prevent the destruction of portions of the settlement by agricultural activity. The expansion of the local cattle breeding cooperative from 1964 onward is amply documented in Csalog's reports on his personal inspections of the site. The cooperative constructed a series of new cattle stalls and large pit silos on the highest part of the settlement's lakefront area, thereby destroying the focal habitation area of the tell-like settlement. This process peaked during intensive building activity between 1970 and 1974; in fact, Korek's large-scale salvage excavation in 1970 was

designed to uncover and document as much of the site as possible. Although the excavation was undertaken under the auspices of the Hungarian National Museum, it proved impossible to halt construction activity or at least to coordinate it with the archaeological work on the site. Hegedűs's excavation on behalf of the Koszta József Museum, in Szentes, in 1978, was necessary for the same reason. The lack of ability and means to protect archaeological heritage and to enforce related laws from the 1960s to the 1980s can in part be attributed to the period's dictatorial system and its mechanisms, which often lacked even a semblance of rationality. Yet, even after the political transition of 1989, two huge manure pits belonging to cattle stalls were cut into the site's northern part sometime between 2004 and 2007, without any notification reaching the official archaeological institutions, which were only informed about the construction much later. Based on images from Google Earth, the smaller manure pit measured roughly 80 × 28 m and the larger one roughly 156 × 38 m, and both were enclosed within the same low earthen bank. As a result of this destruction, the Late Neolithic settlement on the shore of former Lake Kontra offers a dismal sight today.

Recent research at and re-interpretations of Szegvár-Tűzköves

It seemed to us that the time had come to take a fresh look at Szegvár-Tűzköves by re-examine the overall picture of the site in the light of new research findings, and to document its current condition. The necessary background to this work was provided by the collaborative project between the Romano-Germanic Commission (RGK, after the German) of the German Archaeological Institute (Frankfurt am Main) and the Institute of Archaeological Sciences of the Eötvös Loránd University (Budapest) begun in 2018. The first results of the work, carried out on the Late Neolithic settlements of Öcsöd-Kováshalom and Hódmezővásárhely-Kökénydomb, which shed new light on the spatial organisation of these two settlement complexes and offer an entirely new perspective for their interpretation, have already been published (Füzesi *et al.* 2020; Raczky *et al.* 2021). In the case of Szegvár-Tűzköves, we looked at the site on the level of the finds, the buildings and the settlement itself. In the following, we offer a description and discussion of the finer details that can be added to the earlier overall picture of the site.

Human figurines

Previous investigations at Szegvár-Tűzköves gave rise to a spate of uncontested assumptions that wielded, and still wield, considerable influence on current discourse in Hungarian prehistoric studies. One of the most persuasive, first put forward by János Makkay, was one of the mainstays of his scholarly oeuvre. In Makkay's view, the formal and cognitive traits of the seated male figurine portrayed with a sickle or a sickle-shaped curved weapon over his shoulder (Fig. 2.1) were best paralleled by the depictions and mythical deeds of the Greek god Kronos and the Near Eastern gods Kumarbi and Enlil (Makkay 1963, 1964, 1978, 1979, 2005), a view he still upheld in unchanged form in 2005: 'In this sense, it is not mere chance that the Szegvár figurine parallels the Near Eastern male deity with the sickle attribute of the 4th and 3rd millennia, and neither can it be regarded as a reflection of an entirely independent, parallel development. It is an imagery inherently related to the latter both in form and in its evolution' (Makkay 2005, 119).

The mainspring of this comparison was Makkay's stubborn insistence on the traditional chronological scheme, in which the Tisza culture – and thus the Tisza culture settlement at Szegvár – dating from the turn of the 4th to 3rd millennium BCE

(see chronological chart in Makkay 1982a, 153), despite the discrepancy between these non-chronometric dates and the six radiocarbon dates obtained on samples collected from Horváth's small sounding in the site's undisturbed area in 1986, which firmly date the layer sequence of the Tisza culture to the turn of the 6th to 5th millennium and the early 5th millennium BCE (Hertelendi and Horváth 1992, 861). The radiocarbon dates for the Tisza culture give a time span of 4970-4410 BCE and 5110-4450 BCE, respectively (Hertelendi *et al.* 1995, 242, Fig. 2, 1998, 664), with the implication that the Tisza culture had preceded the cultural context of the deities cited by Makkay as parallels to the Szegvár figurine by some 2000 years. An overview of the available radiocarbon dates published in 2009 noted that the summed probabilities for all 107 Late Neolithic samples from the Great Hungarian Plain combined were 5021-4402 BCE (Yerkes *et al.* 2009, Fig. 4.). Viewed from a broader perspective, the discrepancies between the dates proposed for the Late Neolithic of the Tisza region can be explained by the discrepancies between the traditional and the calibrated radiocarbon chronology as outlined by Colin Renfrew. The use of calibrated radiocarbon dates indicated that there was a chronological gap between the archaeological cultures of the Near East, on the one hand, and the Aegean and Europe, on the other, and the prehistoric cultures of Europe were pushed back in time to a much earlier period (Renfrew 1973, 115-120, Figs. 20 and 21). In this new chronological framework, the Tisza culture, and with it the Late Neolithic Tisza – Herpály – Csőszhalom complex of the Great Hungarian Plain, were roughly dated to the period 5000-4500 BCE (Sherratt 1983, Fig. 6; Ehrich and Bankoff 1992, Vol. 2, 343, Fig 1; Whittle 1996, Fig. 3.4; Parkinson 2006, Fig. 4.4; Raczky 2007, Fig. 10; Kienlin 2012, Fig. 2), whereas the traditional chronology put it between 2800 and 2500 BCE (see chronological charts in Kalicz 1970, 70; Makkay 1982a, 182).

For a long time, the Sickle God of Szegvár was indeed unique in the Neolithic cultures of Europe and therefore the search for possible connections with distant cultures was to some extent quite understandable. A male figurine found in 1989 (Fig. 2.5) portraying a seated figure holding a small clay axe over his shoulder added a new dimension, at least on a regional scale (Trogmayer 1990, 66-69, Fig. 82-84; Hansen 2000, 115-118). As a matter of fact, Csalog had earlier published a solid and a hollow seated figurine from Lengyel contexts (Csalog 1960a, 194, Figs. 11 and 12). The three miniature clay axes and the fragments of several miniature clay stools found at Szombathely-Oladi-plató, a site of the Late Neolithic Lengyel culture in Transdanubia, were suggested by Gábor Ilon to come from figurines of what he termed Axe Gods portrayed seated on a low stool or throne (Ilon 2009, 227, Fig. 2.1-3). More recently, an assemblage of clay figurines arranged into several groups was discovered in a house of the late Vinča culture at Crkvine-Stubline (Serbia), and some of the figurines in it also held axes, while the attribute of a larger figurine was a spherical sceptre- or mace-like artefact (Crnobrnja *et al.* 2010, Figs. 5, 10 and 11; Crnobrnja 2011, Figs. 3-10; Spasić 2014, Figs. 3 and 4). Quite obviously, the small axes, the attributes of the clay figurines, were encoded with some sort of meaning in line with the community's norms and social values. Their symbolic role, differing markedly from the quotidian use and meaning of the large stone implements, is indicated by one of the male burials uncovered on the tell settlement of Polgár-Csőszhalom. The burial was unusual in that it contained two polished stone tools (a shoe-last celt and a triangular shaft-hole axe) (Raczky and Anders 2017, 66, Fig. 6.3 (Burial 1, Location A)); none of the other male burials of the single-layer settlement had been outfitted with two stone tools. Microscopic examination of the two stone implements revealed that the wear marks left by their use had been carefully obliterated along the convex edges of both artefacts but are still present on the heels, suggesting that these artefacts had been deliberately removed from the profane realm of their everyday use and set into a new context, whereby they became object-signs vested with an entirely new meaning. Dušan Borić, Ilia

Palaguta and Svend Hansen argued that the contexts of the Szegvár and Stubline figurines strongly suggest that the clay sickles and axes can be seen as precursors to the symbols and tokens of power seen in the Neolithic and Copper Age in the Balkans (Borić 2015a, Fig. 49.6a-c; Palaguta 2018, 634-637, Figs. 6 and 7; Hansen 2017, 122-123, Figs. 7 and 8, 2020, 57-58). This suggestion seems to be underpinned by the sickle-shaped artefact of sheet gold recovered from Grave 36 of the Copper Age cemetery of Varna I (Bulgaria), dated to the mid-5th millennium BCE (Hansen 2020, 58, Fig. 8), which bears a striking resemblance to the copper implement from Zalaszentmihály (Csalog 1960b, Fig. 1.1). The symbolic role of sickles is underscored by some of the 31 burials uncovered on the tell settlement of Gomolava: the burials all contained interments of adult and juvenile males, many of which yielded the remains of sickles, represented by the chipped stone inserts that had once been set into an organic haft (Borić 2015b, 170-172).

Hansen also pointed out that in addition to containing stone and copper axes, several of the graves of the Varna I cemetery contained jade axes that originated from the Alps; being made from a prestigious raw material, these could also be seen as tokens of power (Hansen 2020, 52-54, Fig. 1). For example, Grave 43 of the Varna I cemetery was richly furnished with, among others, grave goods of copper, gold and *Spondylus* shell, as well as stone and copper axes and two Alpine jade axes (Pétrequin *et al.* 2012, Fig. 11). A similar symbolic importance can be ascribed to the hoards of jade axes found at the sites of Orlovets and Svoboa (southern Bulgaria), because in addition to personal references, they also embodied community and group references (Pétrequin *et al.* 2012, 1245-1246, Fig. 13, 1247-1252, Fig. 14), thereby highlighting the wide-ranging prehistoric cultural and exchange networks that can be reconstructed from Italy, to the Balkans, to the Aegean (Sørensen *et al.* 2017, Fig. 2). Jadeite (metaphiolite) from Monte Viso (Italy) and a jade axe had also reached the Tisza culture, as evidenced by a jade axe from the Hódmezővásárhely-Gorzsa settlement (southern Great Hungarian Plain, Hungary) (Bendő *et al.* 2014, 190, Table 1; Biró *et al.* 2017, 454, Fig. 17.1). The distribution of Alpine jade axes in the Carpathian Basin during the Late Neolithic is uneven, with, for the Lengyel culture, higher frequencies on Transdanubian sites than on the Great Hungarian Plain (Biró *et al.* 2017, 436, Fig. 2). Even more striking is the fact that the extraordinarily richly outfitted Lengyel burials mostly contain jade axes, one case in point being the Lengyel culture burials uncovered at Alsónyék-Bátaszék (Tolna county, Hungary) (Biró *et al.* 2017, 457-461, Figs. 20 (Grave 3060), 21 (Grave 6380), 22 (Grave 6348), 23 (Grave 792), and 24 (Grave 3099)). The range of other articles in the Alsónyék-Bátaszék burials suggest that, similarly to the grave goods of the Varna I cemetery, these artefacts were the material expressions of an incipient institutionalised power – in the case of the interred individuals, the material tokens of status (Renfrew 1978; Chapman 1991; Zalai-Gaál 2002; Siklósi 2013, 247-254; Whittle 2018, 182-185; Hansen 2020, 48-61). Another interesting point regarding the Alsónyék-Bátaszék burials with jade axes assigned to the earlier 5th millennium BCE is that these lavishly furnished burials usually had some of sort mortuary structure resting on sturdy posts erected over the interment as indicated by the postholes in the four corners of the grave pits (Zalai-Gaál and Osztás 2009, Figs. 1.8, 2, 3, 5 and 7; Osztás *et al.* 2013, Figs. 3.7 and 8 and 4). It would appear that these unusual mortuary structures can be regarded as the architectural expressions of social differentiation, a special form of making things visible in the above-ground visual sphere (Zalai-Gaál *et al.* 2012a, 2012b, Figs. 1 and 2). The mortuary structures of the Lengyel culture documented on this Transdanubian site are not unique: comparable structures have been uncovered by Horváth on the Late Neolithic tells of Hódmezővásárhely-Kökénydomb and Hódmezővásárhely-Gorzsa (Horváth 1990), an indication that there was a high degree of similarity in the articles and mortuary structures used for social display in the Late Neolithic of the Carpathian Basin (Whittle 2018, 182-183).

It seems likely that the European exchange network of exotic raw materials in the 5th millennium BCE involved the spread as well as the convergence of social values and norms, in the wake of which certain artefacts with a primary function were ascribed a symbolic meaning within the interpretative range of a cultural entity, thereby creating and maintaining a specific mode of social communication. There is compelling evidence for similar object-signs in western Europe, for example from the Neolithic of northern France (Cassen *et al.* 2018). Moreover, the use of other object-signs distinctive to a specific cultural milieu on a regional level within Europe also seems likely (Siklósi 2013, 255-262; Borić 2015a; Hansen 2020; Chapman 2021). The examples cited above strongly suggest that the sickle and the axe became vested with symbolic meaning during the internal development of the south-east European Neolithic. Their symbolic meaning(s) were not simply related to the power sphere; they were also definitely gender charged (Borić 2015a, 946). The archaeological record thus indicates that the Szegvár figurines portrayed with the attributes of a sickle and an axe are not unique in the European archaeological record and that there is no good reason to interpret them as depictions of deities (Makkay 2005).

The five figurines from Szegvár (Fig. 2) also share another common trait, one that has been generally overlooked by Hungarian archaeological scholarship. The first, as Zsuzsanna Siklósi pointed out, is that, similarly to the three hollow female figurines of Hódmezővásárhely-Kökénydomb (formerly described as Venus figurines), their probable findspots all lay in the main habitation area of the tell-like settlement, the mound overlooking the lake (Siklósi 2013, 260), suggesting that their use can be linked to a focal location within the settlement. The second is that all five figurines were found in a strongly fragmented condition and that their findspots can be regarded as secondary, raising the possibility that the process of their modelling, their manipulation and their breakage were intrinsic to their function. The finished figurine thus did not merely convey a static meaning; its intended message encapsulated the entire range of activities, the chain of associated community acts, which thus had a temporality to it (Chapman 2000; Gaydarska *et al.* 2007; Bailey 2017, 827-829). As Dragoş Gheorghiu aptly noted, 'this means that not only the figurines' existence had a social importance, but also the whole process of revealing them, […] ranging from the evocation of the mental model to its materialisation by means of a ritual construction, and up to their ritual consumption' (Gheorghiu 2010, 69). It also seems likely that the modelled figurines impacted the senses in many different ways and that their message was conveyed through several conduits of communication (Bailey 2017, 839-844; Bánffy 2017, 722-724).

In contrast to their dynamic life-histories, a different attitude is embodied by the elaborate assemblages in which the figurines formed a long-term, static collection within a particular building. One special assemblage of this type was found in a burnt building of the tell settlement of Vésztő-Mágor (southern Great Hungarian Plain, Békés county, Hungary) (Hegedűs and Makkay 1990, 104-116, Figs. 134 and 135). It seems that in addition to being the setting of daily activities, some buildings also accommodated the paraphernalia of various non-domestic activities, possibly in a discrete area, in a 'cult corner' (Bánffy 1991, 209-217; Whittle 2018, 148-150). There is also evidence in the archaeological record of the Tisza region, as well as of the Balkans, that some buildings were the locations of the special community activities of larger social groups (Raczky and Sebők 2014), although it would be inappropriate to designate these buildings as sanctuaries or temples (Bernbeck 2013; Lichter 2014).

Burnt houses

The first of Csalog's lengthier excavation reports, focusing on House E, uncovered in Trench VII in autumn 1957, was published in 1958 (Fig. 4). One of the perhaps most far-reaching assertions made in this study was that the burnt debris and the hearth remains suggested the former presence of a building measuring roughly 6-8 m ×

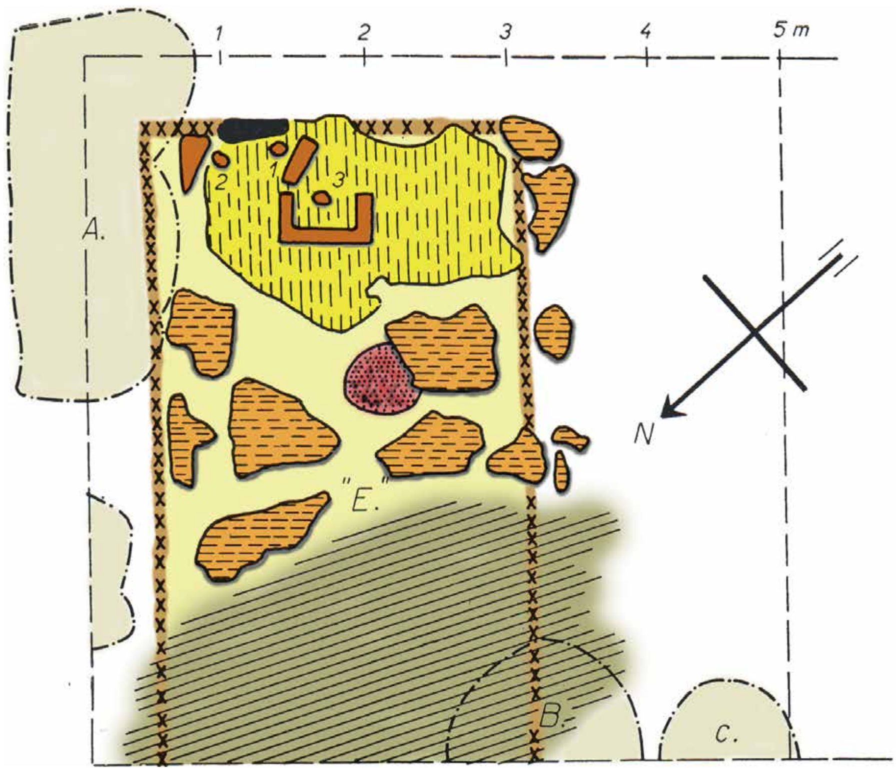

Figure 4. 1-3 Ground plan and reconstruction of House E at Szegvár-Tűzköves (Tisza region, Hungary) (after Csalog 1958, Pls. 1, 2 and 4). The location of House E is shown in Figure 11.

3.4 m. It proved impossible to observe any postholes in the strongly mixed soil, and Csalog's reconstruction thus featured a daub house with a saddle roof, lacking vertical walls (Csalog 1958, 95-101, Figs. 1, 2 and 4). This reconstruction was strongly influenced by the shepherd's hut-like house type reconstructed by Banner based on the observations made during his excavation at Hódmezővásárhely-Kökénydomb and analogies taken from folk architecture (Banner 1929, 1930). This reconstruction dominated Hungarian prehistoric studies for a considerable time; as late as 1980, the same type of building was used for illustrating a reconstruction of the Kökényomb houses and presented as the typical Late Neolithic house on the Great Hungarian Plain (Kalicz 1980, Fig. 27), while the houses of the preceding Alföld Linear Pottery culture were described as sunken pit-dwellings, based on the excavations at Gyoma and Szarvas (Békés county, Hungary) (Makkay 1982b).

In 1964, Csalog excavated a large rectangular building measuring 14.5 × 5 m at Szegvár, in Trench IX (Fig. 5; House K), which yielded a rich array of finds (Koszta József Museum, Archives, drawing accompanying the field documentation). The carefully documented fieldwork, undertaken in 1 × 1 m squares, brought to light the burnt remains of an above-ground building with upright walls. Regrettably, this important discovery remained unpublished, as did the rich find material of the excavation. Korek was the first to uncover the vertical wall section of a house, in his Trench XVII (House L), during his excavation in 1970, and in the later overview of his work on the site he described the houses of the Tisza culture as buildings with vertical wattle-and-daub walls (Korek 1990, 59). In his comprehensive overview of the Neolithic settlement history of the Tisza – Herpály – Csőszhalom complex in the Tisza region, Horváth made a convincing case for the prevalence of timber-framed houses with walls of wattling daubed with clay (Horváth 1989).

Regrettably, no other buildings with a clearly established and appropriately documented ground plan and properly recorded internal furnishings have been published from the Late Neolithic settlement of Szegvár-Tűzköves since Csalog's study on House E. The first systematic overview of the stratigraphic position of the

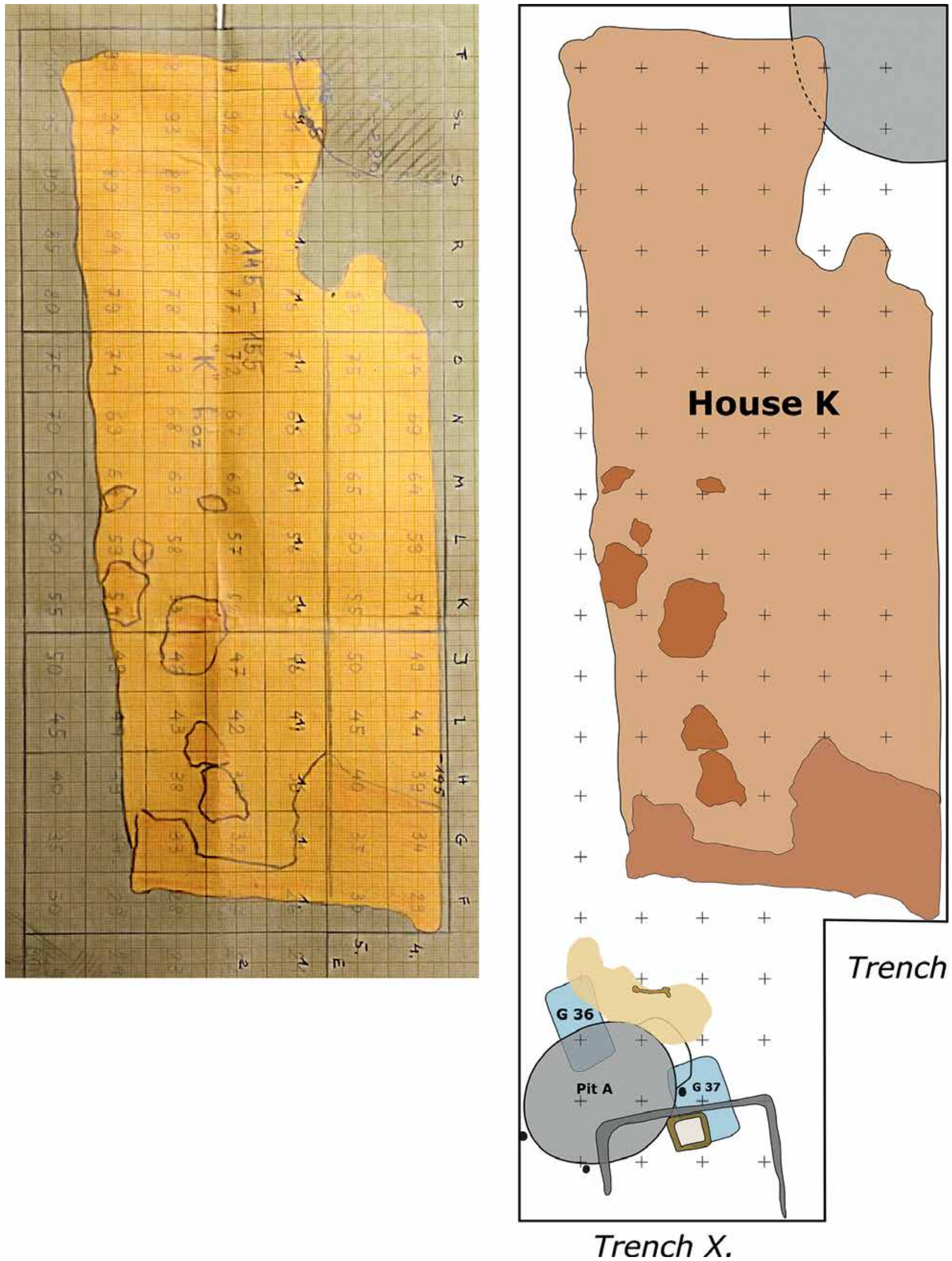

Figure 5. Original excavation drawing of House K at Szegvár-Tűzköves (Tisza region, Hungary), made by József Csalog in 1964 (courtesy: archives of the Koszta József Museum, Szentes, Hungary). The location of House K is shown in Figure 11.

settlement's excavated houses, labelled from A to O, and whatever other details could be gleaned from various documents was provided by Seleanu in her master's thesis (Seleanu 2014, Table 5). According to her, almost nothing is known about Houses A and B, not even their location, and it can at most only be assumed that their remains lay in Trial Trenches I or II or in Trench I. In 1956, the second excavation season, the numbering of the houses continued, with Houses C and D. Nothing is known about Trench VI, of the third campaign, in 1957 (Seleanu 2014, 9). Thus, our overall picture of the houses of the settlement at Szegvár-Tűzköves remains uncertain, and this uncertainty is further compounded by the controversial descriptions in the field diaries, in which burnt patches of clay are variously interpreted as the remains of independent houses and simply as burnt features. Despite these uncertainties, based on Seleanu's work, Korek distinguished five superimposed levels with houses between the relative depths of 50 and 250 cm from the disturbed modern surface. He calculated a total number of between 22 and 34 houses in the 1683 m^2 area

investigated during the successive campaigns on the site (Trenches I-XXV) in a table summarising the available data, although without citing any data on their exact location (Korek 1990, 57-58). In sum, one of the major lacunae in Hungarian prehistoric studies is an overall plan of the location of the assumed houses on the settlement of Szegvár-Tűzköves.

Size and internal organisation of the tell settlement

Following his rescue excavation in 1970, Korek discussed the occupation patterns of Szegvár-Tűzköves in his CSc thesis (Korek 1972, 131). He estimated that the tell-like settlement covered a total area of some 11 ha, an estimate that he later modified, distinguishing a tell-like settlement of 4 ha and a single-layer settlement of 7 ha (Korek 1990, 56). His estimates, although based on rather uncertain personal impressions, remained uncontested in Hungarian prehistoric studies, similarly to Makkay's identification of the clay figurine holding a sickle with a Kronos/Enlil/Kumarbi-like deity and the belief that saddle-roofed huts without upright walls were the norm. Makkay proposed a figure of 1177 occupants for the settlement's population based on the settlement's presumed size, from which the simultaneous presence of 235 houses was calculated, based on the assumption of five people per household (Makkay 1982a, 132-133). These estimates led to a broad-brushed historical picture, according to which the Late Neolithic tells of the Tisza culture and the Balkans emerged in the wake of a socio-economic development, which was essentially identical with the economic and social processes that led to rise of complex societies in the Near East (Makkay 1982a, 111, 2004, 34).

Given the current archaeological record, tells do indeed appear to show similarities, at least formally, from the Near East to the Carpathian Basin. Yet, if we view tells as an expression of community architecture, the title of one of Ian Hodder's studies (2013), 'From diffusion to structural transformation: The changing roles of the Neolithic house in the Middle East, Turkey and Europe', seems apt. The rise of tells can in essence be explained by a 'patchwork of contingent developments in which subsistence activity was repeatedly reconfigured in relation to ecological and social condition' (Thomas 2015, 1075). Community practices associated with tells had an entirely different choreography from one site to the next (Bailey *et al.* 1998, 375-377). It seems to us that the monumental mass of the tells and their changing internal configuration encapsulated a community's collective mentality and were formal expressions of institutionalised activity norms contingent on temporal dynamics. At the same time, one basic precondition to the emergence of tells was the 'nucleation of people in households living close to one another' (Chapman 1997, 143).

Aside from lamenting the dire history of the Szegvár-Tűzköves site and the transformation of the former landscape for the worse, few attempts were made to reconstruct the settlement's former environment and its spatial organisation. Among the attempts that were made, the work by Gábor Rezi-Kató (2009) and Sándor Gulyás and Pál Sümegi (2011) definitely deserves to be mentioned. The former proposed a research agenda outlining the main research directions that would ensure that the previously excavated features and assemblages would become suitable for assessment and interpretation. Taking our cue from this agenda, we undertook our own investigation of this iconic site. Our basic assumption was that the settlement had not been destroyed in its entirety and that a complex investigation of the site aimed at clarifying the settlement's one-time extent and its spatial organisation would yield rewarding results.

The topography of the Szegvár settlement has changed immensely owing to the twentieth-century earth-moving and construction activities on the site, to the extent that no-one had even attempted to reconstruct its original condition. Not even the maps of the Second MOS, made in the nineteenth century and so often cited

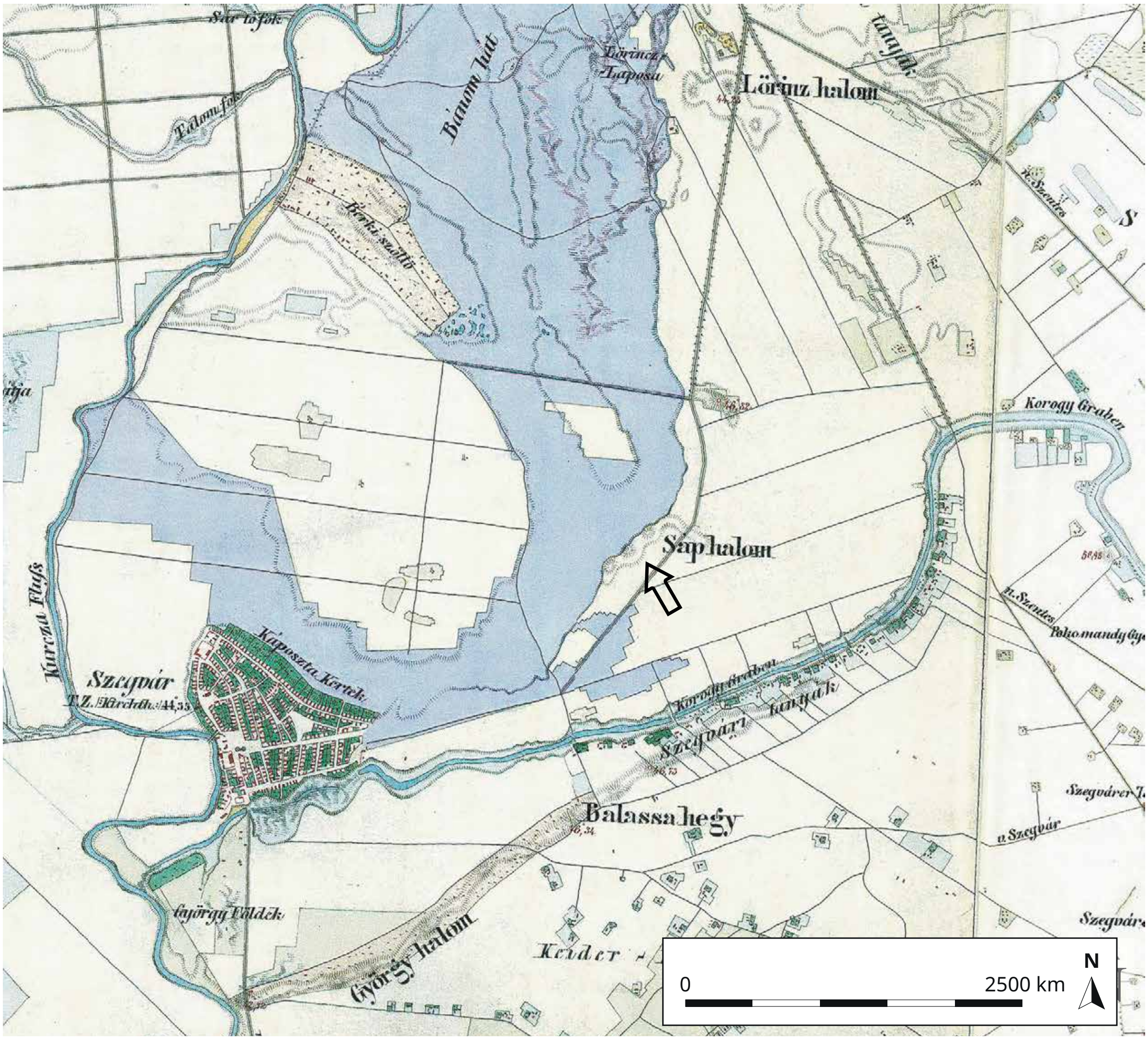

Figure 6. Map of the Second Military Ordnance Survey (Kingdom of Hungary, 1819-1869), showing a line of three mounds in north-south alignment called the Sáp mounds, overlooking Lake Kontra, modified to show the location of the site of Szegvár-Tűzköves (Tisza region, Hungary). © Österreichisches Staatsarchiv ('Second military survey of the Habsburg Empire [1819-1869]', Hungary [B IX a 1124]).

in archaeological studies, were consulted, even though the dominant landscape features, such as Lake Kontra, lying between the Kurca and Kórógy streams, as well as the north-south oriented triple hill on its shore, can be clearly made out on the relevant map section (Fig. 6) (Second MOS, Kingdom of Hungary (1819-1869)). Although fully aware of the uncertainties of previous geodesic surveys, Rezi-Kató nevertheless prepared a 3D terrain model of the settlement's environment (Rezi-Kató 2009, Figs. 1.1 and 1.2) and determined the location of the excavation trenches opened between 1955 and 1986 as well as of the excavated houses on the topographic map (Rezi-Kató 2009, Figs. 2.1, 2.2, 3.1, 3.2, 4.1 and 4.2). The variance between the previous and the new estimates of the site's extent and boundaries is shown on the 3D terrain model (Fig. 7). The relevant section of Google Maps also shows the cattle stalls occupying the northern part of the settlement's lakefront area and the 11 large pit silos in its southern zone, a rather dismal sight regarding the archaeological investigability of the site (Fig. 8).

Following the research activities of the Szegvár-Tűzköves site outlined in the above, in autumn 2020 and spring 2021, we conducted an extensive magnetometer survey of the site, with the support of the RGK (Fig. 9). A SENSYS MXV3 Compact Survey System was used for the geomagnetic data collection. SENSYS MX is a multi-channel measurement system equipped with FGM650 gradiometers. During measurement,

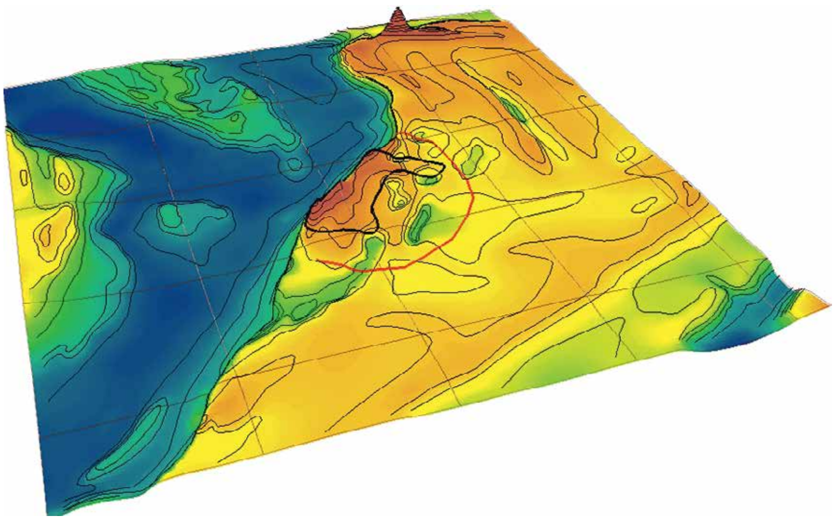

Figure 7. 3D terrain model of Szegvár-Tűzköves (Tisza region, Hungary) showing the previous and the new estimates for the extent of the occupied area.

Figure 8. Combined elevation model of Szegvár-Tűzköves (Tisza region, Hungary), showing the areas disturbed by agricultural facilities.

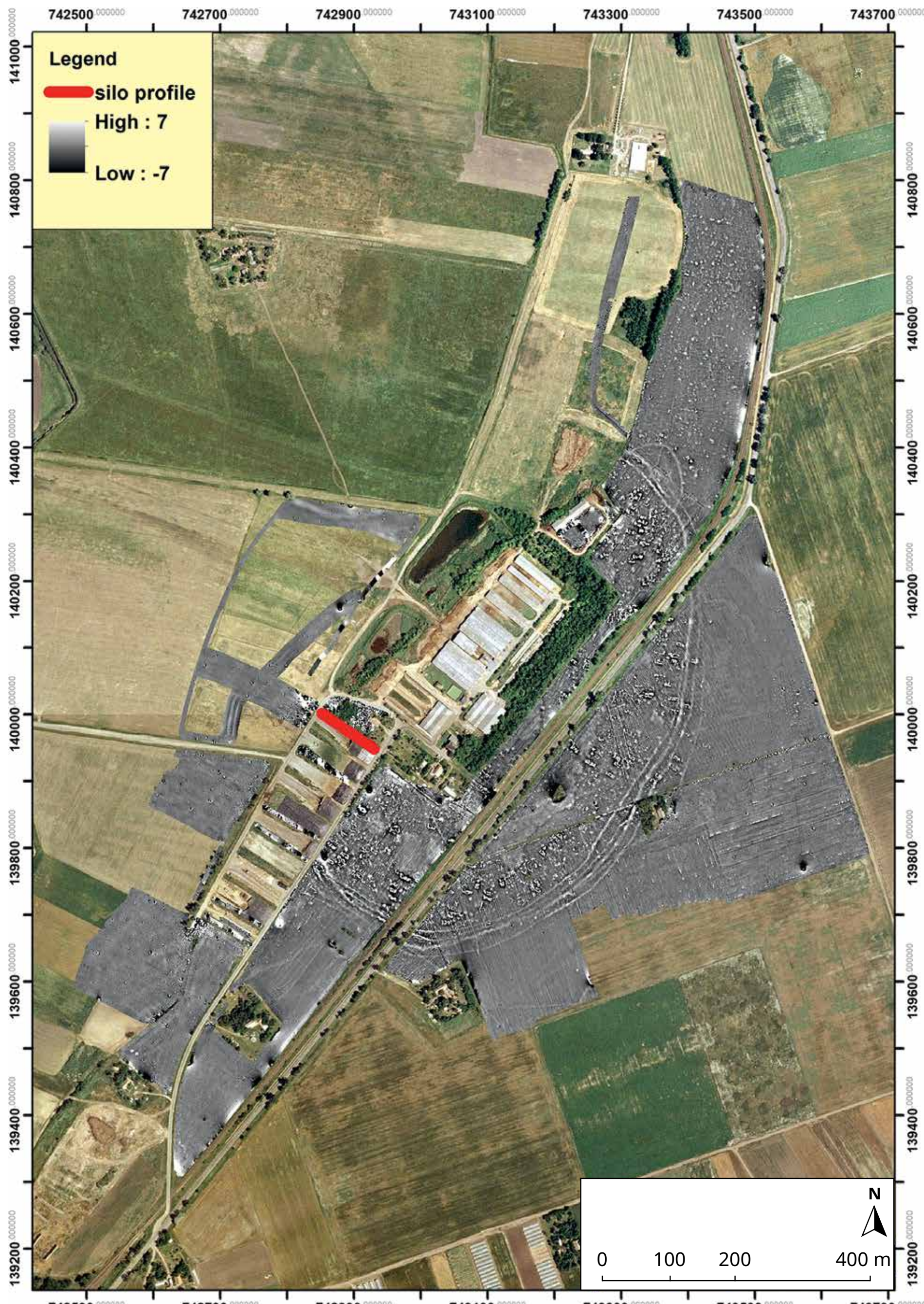

Figure 9. Survey magnetogram of Szegvár-Tűzköves (Tisza region, Hungary), showing the extent of the settlement, the central areas of the mound disturbed by agricultural facilities, and the location of ditch (red) shown in Figure 10.

each piece of equipment is set up with a JAVAD GNSS RTK-GPS system (base-rover setup), enabling it to collect data with accurate coordinates and thus complying with the NMEA 0183 standard. Magnetometers are mounted on a non-magnetic carrier, which carries 16 sensors set 25 cm apart. While the distance between the sensors is fixed along the array (*x*-axis), measurements along the track (*y*-axis) depend on the speed of survey, as the sensors read magnetic data at fixed time intervals; a faster movement of the array results in fewer readings, and *vice versa*. To allow for data forwarding and to ensure GPS accuracy, the speed of the motorised vehicle was restricted to a maximum of 15 km/h, which roughly equals a 3-6 cm point density along the track. Data acquisition was provided by the MonMX 4.0 software, which communicates with the MXcompact box of the multi-channel system. The software interface was used for configuring channels

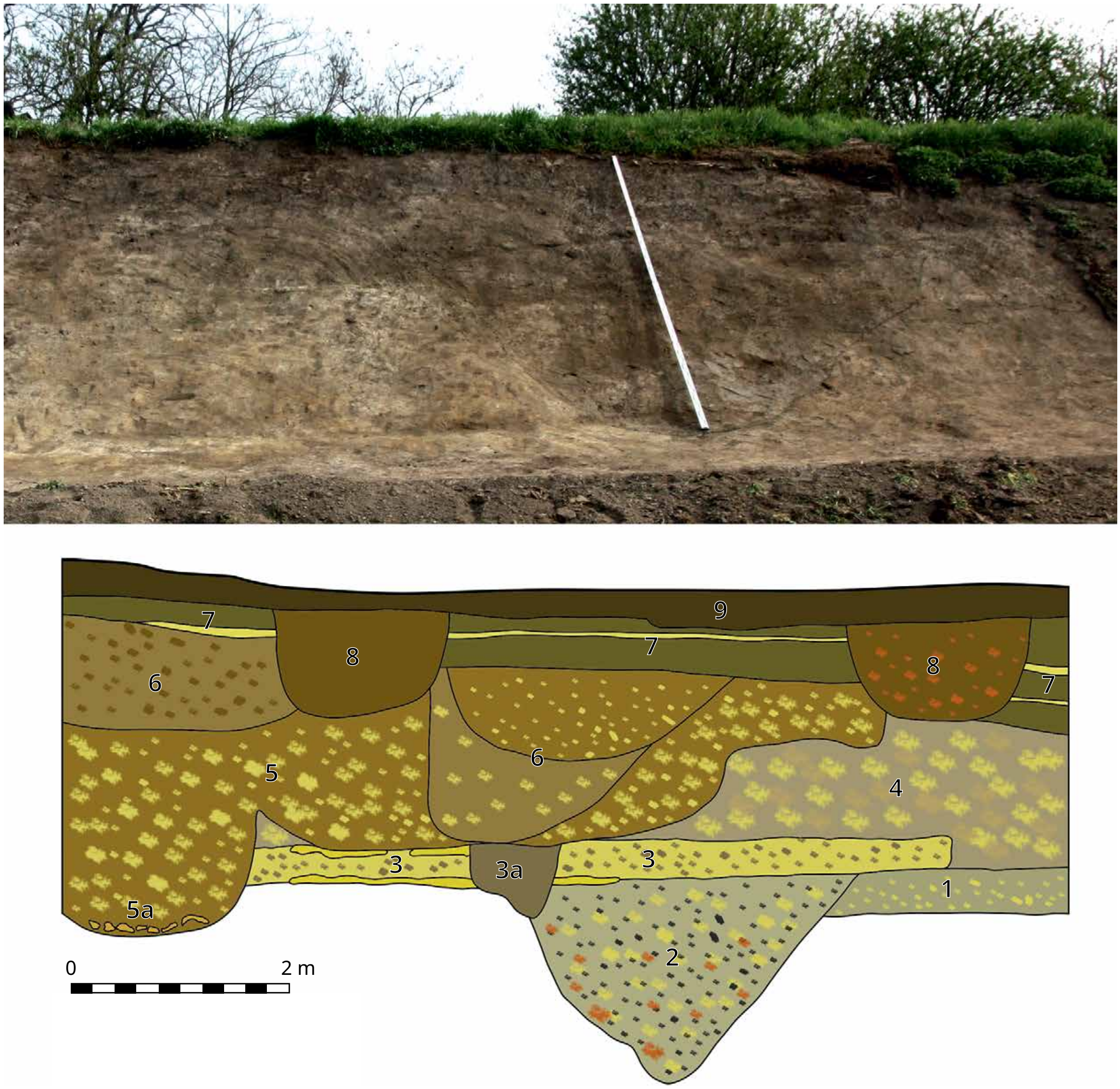

Figure 10. Photo of a section of a V-shaped ditch on the western wall of the northernmost pit silo, part of the ditched enclosure system ringing the settlement of Szegvár-Tűzköves (Tisza region, Hungary), taken in 2021. The exact location of the ditch is shown in Fig. 9.

and sensor compensation prior to a survey. It also enabled the surveyor to navigate the landscape and helped in creating an even coverage of the survey area. Altogether, 47.6 ha were surveyed during the field campaign, in several discrete units.

The survey revealed that, despite the destruction and the fact that some areas were covered by cattle stalls, the extent of the one-time settlement could be accurately determined, as could its spatial organisation (Fig. 11). The magnetogram indicated that the settlement was ringed by a multiple enclosure system, usually comprising three parallel curvilinear ditches, but in some sections two or four ditches, adjoined by a semi-circular enclosure with a radius of 50 m in the north-east. The exact chronological relationships among the ditches remain uncertain. The ditches enclosed an elliptical area roughly 800 m long × 400 m wide. We succeeded in mapping about two thirds of the enclosure system that ringed the settlement, from the section in the north-east to that in the south-west. We were unable to map the section that lay in the settlement's strongly disturbed area. The remnants of the settlement could still be made out in the walls of the pit silos, and we were able to document a section of the roughly 4 m deep V-shaped ditch in one of the pit silos (Fig. 10).

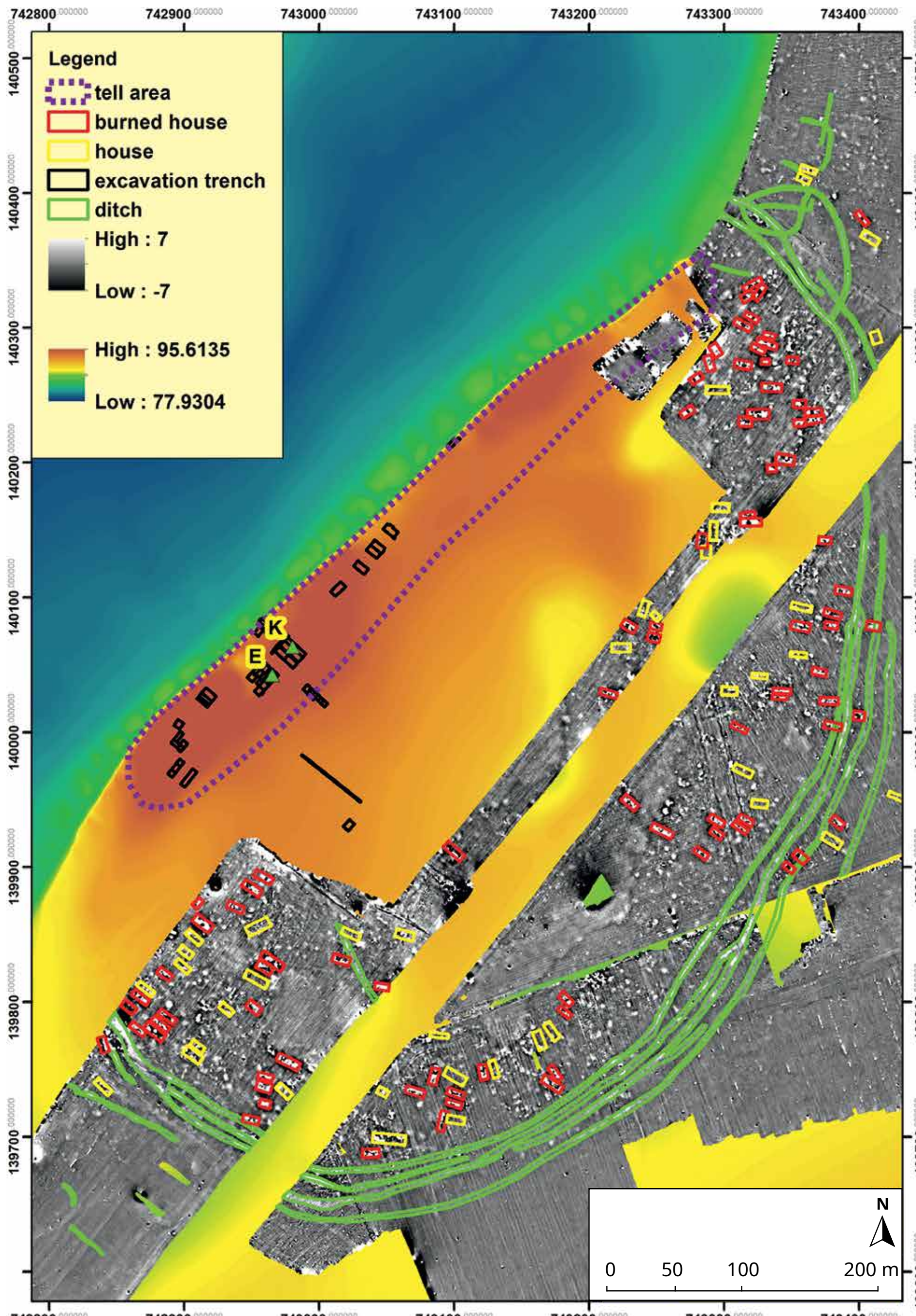

Figure 11. Survey magnetogram of Szegvár-Tűzköves (Tisza region, Hungary), showing the location and dimension of enclosing ditches (green), burnt (red) and unburnt (yellow) houses, and destroyed central mound (burgundy) with the previous excavation trenches (black), and Houses E and K (black on yellow).

One of the most important results of the geophysical survey was that the settlement's eastern boundary extended some 150 m eastward from the railway embankment, which is oriented NE – SW. The surveys demonstrated that Szegvár-Tűzköves covered an area of roughly 32 ha, far more than the earlier, estimated area of 11 ha, and that the settlement has not been wholly destroyed, a promising prospect for future investigations. Various features could be identified among the magnetic anomalies, rectangular house plans among them, whose number totalled between 110 and 120 (Fig. 11). These house remains all appeared to be strongly burnt. In 2022, we also noted two important phenomena when we cleaned the profile of two roughly 90 m long and 4 m high walls of the northernmost pit silo. The first of these is the presence of the repeatedly renewed, yellow clay floor levels of an

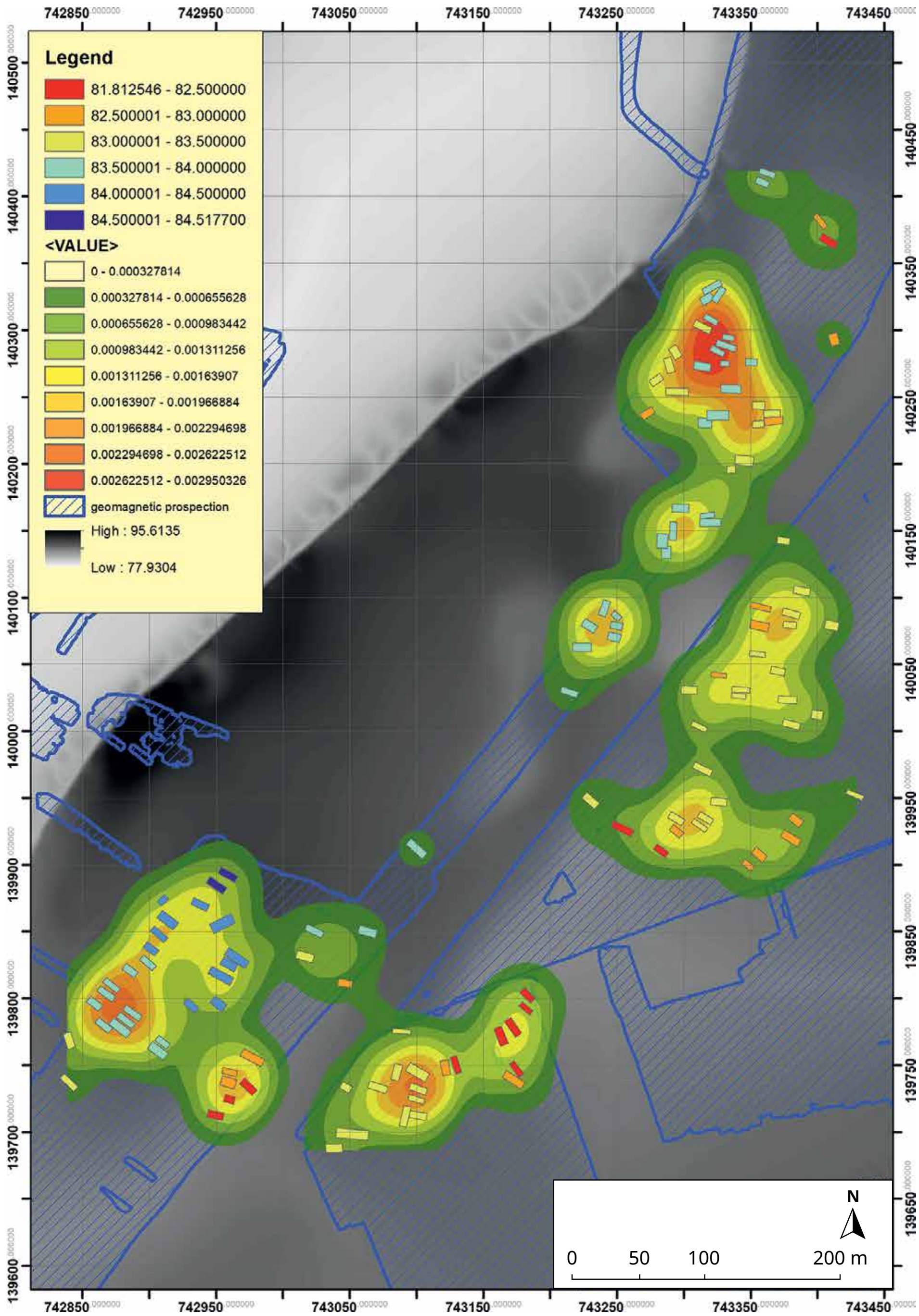

Figure 12. Kernel density groups of the houses appearing on the survey magnetogram of the Szegvár-Tűzköves site (Tisza region, Hungary).

unburnt house in the east – west section of the tell-like area, meaning that in addition to burnt houses, there were also unburnt buildings, and that caution therefore must be exercised in estimating the original number of houses (because the geomagnetic equipment does not detect unburnt houses). The second is, it must also be borne in mind that there were different community activities related to houses, a point already noted in relation to the tell-like settlement complex of Öcsöd (Füzesi *et al.* 2020, 145). Our magnetometer survey indicated intercutting between the ditched enclosure and the former houses, particularly in the east. It seems likely that the houses in this peripheral area represented not one, but several occupation levels. The field data from previous excavations suggested that the layer sequence in this area was no more than 80-100 cm thick, which was also confirmed by recent stratigraphic cores.

Although the rectangular houses were oriented in different directions, they were all aligned towards the lakefront and the main habitation area, suggesting that the settlement's internal layout was based on a centripetal spatial organisation, similar to the one noted at Borđoš (Serbian Banat) (Hofmann *et al.* 2019). The magnetometer survey of the Hódmezővásárhely-Kökénydomb site revealed the exact same spatial organisation (Raczky *et al.* 2021, Figs. 11 and 12), and a kernel density estimate of the houses identified through magnetometry at Szegvár indicated an arrangement into 5 larger and 11 smaller clusters (Fig. 12). The sizes of the houses varied, with most falling into the 50-100 m^2 range. The terrain model and the data of the earlier excavations suggested that the overall area of the three lakefront centres covered some 1.8-2 ha and that it can be regarded as the tell-like part of the settlement (Fig. 10). We know from Horváth's opening of a trench in a small, undisturbed part near the southern edge of this main habitation area, that layer thickness of the Neolithic deposits there was roughly 2.5-2.9 m (Horváth 2004, 6, 11-12).

Our investigations and the information from previous fieldwork have furnished conclusive evidence that, similarly to Hódmezővásárhely-Kökénydomb, Szegvár-Tűzköves was structured both horizontally and vertically and that this configuration was constantly changing (Raczky *et al.* 2020); the lakefront area accumulated into a stratified, oval mound ringed by a less-intense ditched enclosure. At Hódmezővásárhely-Kökénydomb, the settlement's spatial units were separated by semi-circular ditches, while at Szegvár-Tűzköves, the entire settlement was encircled by a ditched enclosure. We hope that systematic geoarchaeological surveys will provide an even more accurate picture of the stratigraphy of the settlement and the layout of its features. The assessment of the still-unpublished finds from Szegvár, currently housed at the Koszta József Museum in Szentes and at the Hungarian National Museum in Budapest, will no doubt also add finer detail to our overall understanding of the site.

Conclusion

In the wake of new archaeological research, it proved possible to reveal new dimensions of the Late Neolithic settlement of Szegvár-Tűzköves and to refute some of the previously uncontested assumptions related to the site.

The clay figurines and face pots from the site fit in nicely with the material imprints of the social and ritual practices of a south-east European community in the earlier 5th millennium BCE. Two of the distinctive aspects of these figurines are their fragmentation and their location of deposition, generally on the central, prominent mound of the settlement. Among the attributes associated with these figurines, the sickle and the axe are artefacts to which symbolic meanings were ascribed in certain social milieus and that were tokens of status in an incipient social ranking in the Late Neolithic of the Carpathian Basin.

More recent investigations have convincingly demonstrated that the houses of the Szegvár-Tűzköves settlement were above-ground, post-framed structures with walls of wattling daubed with clay. Many of these were strongly burnt, suggesting that deliberate acts of house burning were practised over a long timeframe at the settlement (for a comprehensive discussion of the destruction of houses by fire in a broader south-east European context, cf. Tringham 2005). The magnetometer survey revealed that the houses were all aligned towards the central lakefront area.

The magnetic anomalies recorded during the survey revealed an enclosure system of multiple ditches ringing the settlement, which extended over an area of roughly 32 ha. The 1.8-2 ha tell-like mound, which was the main habitation area, lay in the settlement's western part, which suffered extensive damage in the twentieth century.

As was the case at Hódmezővásárhely-Kökénydomb, at Szegvár the tell-like settlement mound and the houses oriented towards a focal area formed a distinctive monumental spatial system on the southern Great Hungarian Plain in the early 5th millennium BCE. Szegvár and Kökénydomb predate, by some 400-500 years, the burnt houses aligned towards a focal area at settlements of the Cucuteni – Tripolye culture, on the eastern fringes of the Carpathian Basin. However, in the case of the latter, the focal reference area was not a prominent mound, but, in general, an empty space. Roughly contemporaneously with the Szegvár settlement, at Polgár-Csőszhalom, in the Upper Tisza region, to the north of Szegvár, the Balkan-type tell was combined with a Transdanubian-type circular enclosure and a central arrangement of houses to form another type of monumental community architecture. Taken together, the archaeological record would suggest that the Late Neolithic communities settling along the River Tisza created a diverse range of settlements, each with its own spatial organisation mirroring distinctive social norms of how horizontal and vertical space was to be ordered at the turn of the 6th to 5th millennium BCE, which in all likelihood reflects a dynamic process of settlement nucleation across this extensive region.

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References

Bailey, D., 2017. Southeast European Neolithic figurines: beyond context, interpretation, and meaning. *In:* T. Insoll, ed. *The Oxford handbook of prehistoric figurines*. Oxford: Oxford University Press, 823-850.

Bailey, D., Tringham, R., Bass, J., Stevanovic, M., Hamilton, M., Neumann, H., Angelova, I., Raduncheva, A., 1998. Expanding the dimensions of early agricultural tells: the Podgoritsa Archaeological Project, Bulgaria. *Journal of Field Archaeology*, 25 (4), 373-396.

Banner, J., 1929. Adatok a Neolithkori lakóház kérdéséhez [Beiträge zur Frage es Neolithischen Wohnhauses]. *Dolgozatok*, 5, 115-131.

Banner, J., 1930. A kökénydombi neolithkori telep [Die Neolithische Ansiedlung von Kökénydomb]. *Dolgozatok*, 6, 49-158.

Banner, J., 1951. A harmadik *ásatás* a hódmezővásárhelyi Kökénydombon [The third excavation on the Kökénydomb at Hódmezővásárhely]. *Archaeológiai Értesítő*, 78, 27-36.

Banner, J., 1960. The Neolithic settlement on the Kremenyák hill at Csóka (*Čoka*). *Acta Archaeologica Academiae Scientiarum Hungariae*, 12, 1-56.

Banner, J. and Foltiny, I., 1945. *Újabb ásatás* a hódmezővásárhelyi Kökénydombon [Neuere Ausgrabungen im Kökénydomb bei Hódmezővásárhely]. *Folia Archaeologica*, V, 8-17.

Banner, J. and Korek, J., 1949. Negyedik *és ötödik ásatás* a hódmezővásárhelyi Kökénydombon (1942. aug. 3-28. *és* 1944. aug. 2-szept. 8) [Les campagnes IV et V des fouilles pratiquées au Kökénydomb de Hódmezővásárhely (3-8 Aout 1942; 2 Aout-8 Septembre 1944)]. *Archaeológia Értesítő*, 76, 9-25.

Bánffy, E., 1991. Cult and archaeological context in middle and south-east Europe in the Neolithic and the Chalcolithic. *Antaeus*, 19-20, 183-249.

Bánffy, E., 2017. Figurines of eastern and central Europe. *In:* T. Insoll, ed. *The Oxford handbook of prehistoric figurines*. Oxford: Oxford University Press, 705-728.

Bendő, Zs., Szakmány, Gy., Kasztovszky, Zs., Maróti, B., Szilágyi, Sz., Szilágyi, V., Biró T., K., 2014. Results of non-destructive SEM-EDX and PGAA analyses of jade and eclogite polished stone tools in Hungary. *Archeometriai Műhely*, 11 (4), 187-206.

Bernbeck, B., 2013. Religious revolutions in the Neolithic? 'Temples' in present discourse and past practice. *In:* K. Kaniuth, A. Löhnert, J.L. Miller, A. Otto, M. Roaf, W. Sallaberger, *Tempel im Alten Orient. CDOG 7, Colloqium 7 in München 2009*. Wiesbaden: Harrassowitz Verlag, 33-47.

Biró T., K., Pétrequin, P., Errera, M., Přichystal, A., Trnka, G., Zalai-Gaál, I., Osztás, A., 2017. Des Alpes à l'Europe centrale (Autriche, République tchèque, Slovaquie et Hongrie) [From the Alps to central Europe (Austria, the Czech Republic, Slovakia and Hungary)]. *In:* P. Pétrequin, E. Gauthier, A.-M. Pétrequin, *JADE : Objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique. Tome 3.1*. Besançon: Presses Universitaires de Franche-Comté, 431-465.

Borić, D., 2015a. Mortuary practices, bodies and persons in the Neolithic and Early – Middle Copper Age of southeast Europe. *In:* C. Fowler, J. Harding, D. Hofmann, *The Oxford handbook of Neolithic Europe.* Oxford: Oxford University Press, 927-957.

Borić, D., 2015b. The end of the Vinča world: modelling the Neolithic to Copper Age chronology and changing settlement patterns. *In:* S. Hansen, P. Raczky, A. Anders, A. Reingruber, eds. *Neolithic and Copper Age between the Carpathians and the Aegean Sea: chronologies and technologies from the 6th to the 4th Millennium BCE. International workshop Budapest 2012*. Bonn: Dr. Rudolf Habelt GmbH, 157-217.

Cassen, S., Valentin Grimaud, V., Pétrequin, P., 2018. Objets-signes et signes de l'object : Iconographie des anneaux et des haches neolithiques dans le nord de la France. *Problemy istorii, filologii, kul'tury Проблемы истории, филологии, культуры*, 2, 227-243.

Chapman, J., 1991. The creation of social arenas in the Neolithic and Copper Age of S. E. Europe: the case of Varna. *In:* P. Garwood, D. Jennings, R. Skeates, J. Toms, eds. *Sacred and profane: proceedings of a conference on archaeology, ritual and religion, Oxford, 1989.* Monograph 32. Oxford: Oxford University Committee for Archaeology, 157-181.

Chapman, J., 1997. The origins of tells in eastern Hungary. *In:* P. Topping, ed. *Neolithic landscapes.* Oxford: Oxbow Books, 139-164.

Chapman, J., 2000. *Fragmentation in archaeology: people, places, and broken objects in the prehistory of south-eastern Europe*. London: Routledge.

Chapman, J., 2009. The Danube and settlement prehistory 80 years on. *European Journal of Archaeology*, 12 (1-3), 145-156.

Chapman, J., 2020. *Forging identities in the prehistory of old Europe: dividuals, individuals and communities, 7000-3000 BC.* Leiden: Sidestone Press.

Childe, V.G., 1929. *The Danube in prehistory*. Oxford: Clarendon Press.

Crnobrnja, A., 2011. Arrangement of Vinča culture figurines: a study of social structure and organisation. *Documenta Praehistorica*, 38, 131-147.

Crnobrnja, A., Simić, Z., Janković, M., 2010. Late Vinča culture settlement at Crkvine in Stubline: household organization and urbanization in the Late Vinča culture period. *Starinar n.s.*, 59, 9-25.

Csalog, J., 1956. Egyiptomi kultúrkapcsolatokról tanuskodnak a Szegvár határában talált *újkőkori* falu leletei. *Viharsarok*, szeptember 30, 4.

Csalog, J., 1957. *Újkőkori* idoljaink arcformájának kérdéséről [On the question of the shape of our Neolithic idols' faces]. *Archeologiai Értesítő*, 84, 207-211.

Csalog, J., 1958. Das Wohnhaus 'E' von Szegvár-Tűzköves und seine Funde. *Acta Archaeologica Academiae Scientiarum Hungariae*, 9, 95-114.

Csalog, J., 1959. Die anthropomorphen Gefässe und Idolplastiken von Szegvár-Tűzköves. *Acta Archaeologica Academiae Scientiarum Hungariae,* 11, 7-38.

Csalog, J., 1960a. Az idolplasztika néhány kérdéséhez [Concerning some questions about idol sculpture]. *Archaeologiai Értesítő*, 87 (1), 188-194.

Csalog, J., 1960b. Das Krummschwert des Idols von Szegvár-Tűzköves. *Acta Archaeologica Academiae Scientiarum Hungariae*, 12, 57-68.

Csalog, J., 1966. A legújabb kökénydombi fonatlenyomat tanulságai [Die Lehren des neuesten Geflechtabdruckes von Kökénydomb]. *Móra Ferenc Múzeum Évkönyve*, 1964-65, 17-45.

Ehrich, R.W. and Bankoff, H. A., 1992. East central and southeastern Europe. *In:* R.W. Ehrich, ed. *Chronologies in Old World archaeology*. 3rd edition. Chicago: University of Chicago Press, 375-394.

Füzesi, A., Rassmann, K., Bánffy, E., Raczky, P., 2020. Human activities on a Late Neolithic tell-like settlement complex of the Hungarian Plain (*Öcsöd-Kováshalom*). *In:* A. Blanco-González and T.L. Kienlin, eds. *Current approaches to tells in the prehistoric Old World*. Oxford and Philadelphia: Oxbow, 137-161.

Garašanin, M., 1951. Die Theiss-Kultur im jugoslawischen Banat. *Bericht der Römisch-Germanischen Kommission*, 33 1943-1950 (1951), 125-132.

Gaydarska, B., Chapman, J., Raduncheva, A., Koleva, B., 2007. The *châine opératoire* approach to prehistoric figurines: an example from Dolnoslav, Bulgaria. *In:* C. Renfrew and I. Morley, eds. *Image and imagination: a global prehistory of figurative representation*. Cambridge: McDonald Institute, 171-184.

Gheorghiu, D., 2010. Ritual technology: an experimental approach to Cucuteni-Tripolye Chalcolithic figurines. *In:* D. Gheorghiu and A. Cyphers, eds. *Anthropomorphic and zoomorphic miniature figures in Eurasia, Africa and Meso-America: morphology, materiality, technology, function and context.* BAR International Series 2138. Oxford: Archeopress, 61-72.

Gimbutas, M., 1974. *The gods and goddesses of old Europe 7000-3500 BC: myths, legends and cult images.* London: Thames and Hudson.

Gulyás, S. and Sümegi, P., 2011. Riparian environment in shaping social and economic behavior during the first phase of the evolution of Late Neolithic tell complexes in SE Hungary (6th/5th millennia BC). *Journal of Archaeological Science*, 38, 2683-2695.

Hansen, S., 2000. Plastik der Jungstein- und Kupferzeit in Ostungarn. *Das Altertum*, 46, 97-132.

Hansen, S., 2007. *Bilder vom Menschen der Steinzeit. Untersuchungen zur anthropomorphen Plastik der Jungsteinzeit und Kupferzeit in Südosteuropa*. Volumes I and II. Mainz: Philipp von Zabern.

Hansen, S., 2017. The iconography of inequality. *In:* S. Hansen and J. Müller, eds. *Rebellion and inequality. Proceedings of the Kiel workshops 'Archaeology of Rebellion' (2014) and 'Social Inequality as a Topic in Archaeology' (2015).* Bonn: Dr. Rudolf Habelt GmbH, 113-133.

Hansen, S., 2020. Varna – Repräsentationen der Macht. *In:* S. Hansen, ed. *Repräsentation der Macht. Beiträge des Festkolloquiums zur Ehren des 65. Geburtstags von Blagoje Govaderica*. Deutsches Archäologisches Institut, Eurasien Abteilung, Berlin. Kolloquien zur Vor- und Frühgeschichte 25. Wiesbaden: Harrassowitz Verlag, 45-72.

Hegedűs, K. and Makkay, J., 1990. Vésztő-Mágor. Eine Siedlung der Theiss-Kultur. *In:* W. Meier-Arendt, ed. *Alltag und Religion. Jungsteinzeit in Ost-Ungarn. Ausgrabungen in Hódmezővásárhely-Gorzsa, Szegvár-Tűzköves, Öcsöd-Kováshalom, Vésztő-Mágor, Berettyóújfalu-Herpály*. Frankfurt am Main: Museum für Vor- und Frühgeschichte, 97-116.

Hertelendi, E. and Horváth, F., 1992. Radiocarbon chronology of Late Neolithic settlements in the Tisza-Maros region, Hungary. *Radiocarbon*, 34 (3), 859-866.

Hertelendi, E., Kalicz, N., Raczky, P., Horváth, F., Veres, M., Svingor, É., Futó, I., Bartosiewicz, L., 1995. Re-evaluation of the Neolithic in eastern Hungary based on calibrated radiocarbon dates. *Radiocarbon*, 37 (2), 239-44.

Hertelendi, E., Svingor, É., Raczky, P., Horváth, F., Futó, I., Bartosiewicz, L., 1998. Duration of tell settlements at four prehistoric sites in Hungary. *In:* W.G. Mook and J. van der Plicht, eds. *Proceedings of the 16th International 14C Conference. Radiocarbon*, 40 (2), 659-665.

Hodder, I., 2013. From diffusion to structural transformation: the changing roles of the Neolithic house in the Middle East, Turkey and Europe. *In:* D. Hofmann and J. Smyth, eds. *Tracking the Neolithic house in Europe.* One World Archaeology. New York: Springer, 349-362.

Hofmann, R., Medović, A., Furholt, M., Medović, I., Stanković-Pešterac, T., Dreibrodt, S., Martini, S., Hofmann, A., 2019. Late Neolithic multicomponent sites of the Tisza region and the emergence of centripetal settlement layouts. *Praehistorische Zeitschrift*, 94 (2), 351-378.

Horváth, F., 1989. A survey on the development of Neolithic settlement pattern and house types in the Tisza region. *In:* S. Bökönyi, ed. *Neolithic of southeastern Europe and its Near Eastern connections. International Conference 1987, Szolnok-Szeged.* Varia Archaeologica Hungarica II. Budapest: Institut Archaeologici Academiae Scientiarum Hungaricae, 85-101.

Horváth, F., 1990. Hódmezővásárhely-Gorzsa. Eine Siedlung der Theiß-Kultur. *In:* W. Meier-Arendt, ed. *Alltag und Religion. Jungsteinzeit in Ost-Ungarn. Ausgrabungen in Hódmezővásárhely-Gorzsa, Szegvár-Tűzköves, Öcsöd-Kováshalom, Vésztő-Mágor, Berettyóújfalu-Herpály*. Frankfurt am Main: Museum für Vor- und Frühgeschichte, 35-52.

Horváth, F., 1994. *A dél-alföldi újkőkorkutatás új szempontjai, módszerei és eredményei.* Unpublished CSc thesis, University of Szeged, Szeged.

Horváth, F., 2004. *Régészeti Értékeink 11. Újkőkori falu Szegvár-Tűzkövesen [Treasures of Archaeology in Hungary 11: the Neolithic village at Szegvár-Tűzköves].* Budapest: Kulturális *örökségvédelmi* Hivatal.

Höckmann, O., 1968. Idolplastik der Theiss- und Bükk-Kultur. *Jahrbuch des Römisch-Germanischen Zentralmuseums Mainz*, 13, 1-29.

Ilon, G., 2009. A Lengyeli-kultúra baltás istene Szombathelyen (Vas megye) [The 'Axe God' of the Lengyel culture from Szombathely (county Vas)]. *In:* L. Bende and G. Lőrinczy, eds. *Medinától Etéig. Régészeti tanulmányok Csalog József születésének 100. évfordulójára*. Szentes: Koszta József Múzeum, 225-228.

Kalicz, N., 1970. *Clay gods*. Budapest: Corvina.

Kalicz, N., 1980*. Clay gods*. 2nd edition. Budapest: Corvina.

Kalicz, N., 2013. Siedlungsstruktur und Bestattungen mit Prestigeobjekten des Fundplatzes Tápé-Lebő (südliches Theissgebiet, Ungarn). *In:* A. Anders, G. Kulcsár, G. Kalla, V. Kiss, G.V. Szabó, eds. *Moments in time: papers presented to Pál Raczky on his 60th birthday*. Budapest: Prehistoric Society and Eötvös Loránd University and L'Harmattan, 365-384.

Kalicz, N. and Raczky, P., 1990. Das Spätneolithikum im Theissgebiet. Eine Übersicht zum heutigen Forschungsstand aufgrund der neuesten Ausgrabungen. *In:* W. Meier-Arendt, ed. *Alltag und Religion. Jungsteinzeit in Ost-Ungarn. Ausgrabungen in Hódmezővásárhely-Gorzsa, Szegvár-Tűzköves, Öcsöd-Kováshalom, Vésztő-Mágor, Berettyóújfalu-Herpály*. Frankfurt am Main: Museum für Vor- und Frühgeschichte, 11-33.

Kalicz, N. and Raczky, P., 1991. Catalogue des objects exposes. *In:* M. Jannet-Vallat, ed. *Les Agriculteurs de la Grande Plaine Hongroise (4000-3500 av. J.-C.).* Budapest: Kossuth Press, 135-149.

Kalicz, N., Ljamić-Valović, N., Meier-Arendt, W., Raczky, P., 1990. Katalog der ausgestellten Funde. *In:* W. Meier-Arendt, ed. *Alltag und Religion. Jungsteinzeit in Ost-Ungarn. Ausgrabungen in Hódmezővásárhely-Gorzsa, Szegvár-Tűzköves, Öcsöd-Kováshalom, Vésztő-Mágor, Berettyóújfalu-Herpály*. Museum für Vor-und Frühgeschichte: Frankfurt am Main, 141-163.

Kienlin, T., 2012. Patterns of change, or perceptions deceived? Comments on the interpretation of Late Neolithic and Bronze Age tell settlement in the Carpathian Basin. *In:* T.L. Kienlin and A. Zimmermann, eds. *Beyond elites: alternatives to hierarchical systems in modelling social formations. International conference at the Ruhr-Universität Bochum, Germany, October 22-24, 2009.* Universitätsforschungen zur prähistorischen Archäologie 215. Bonn: Dr. Rudolf Habelt GmbH, 251-310.

Korek, J., 1987. Szegvár-Tűzköves: a settlement of the Tisza culture. *In:* L. Tálas and P. Raczky, eds. *The Late Neolithic of the Tisza region: A survey of recent excavations and their findings: Hódmezővásáhely-Gorzsa, Szegvár-Tűzköves, Öcsöd-Kováshalom, Vésztő-Mágor, Berettyóújfalu-Herpály.* Budapest: Kossuth Press, 47-60.

Korek, J., 1990. Szegvár-Tűzköves. Eine Siedlung der Theiss-Kultur. *In:* W. Meier-Arendt, ed., *Alltag und Religion. Jungsteinzeit in Ost-Ungarn. Ausgrabungen in Hódmezővásárhely-Gorzsa, Szegvár-Tűzköves, Öcsöd-Kováshalom, Vésztő-Mágor, Berettyóújfalu-Herpály*. Museum für Vor- und Frühgeschichte: Frankfurt am Main, 53-66.

Korek, K., 1972. *A tiszai kultúra* [The Tisza culture]. Unpublished CSc thesis, Eötvös Loránd University, Budapest.

Lichter, C., 2014. 'Temples' in the Neolithic and Copper Age in southeast Europe. *Documenta Praehistorica,* 41, 119-136.

Link, T., 2006. *Das Ende der neolithischer Tellsiedlungen. Ein kulturgeschichtliches Phänomen des 5. Jahrtausends v. Chr. im Karpatenbecken*. Institut für Ur- und Frühgeschichte der Universität Heidelberg, Universitätforschungen zur prähistorischen Archäologie Band 134. Bonn: Dr. Rudolf Habelt GmbH.

Makkay, J., 1963. A Kronos-Kumarbi-Enlil probléma. *Antik Tanulmányok,* 10, 252-262.

Makkay, J., 1964. Early Near Eastern and south east European gods. *Acta Archaeologica Academiae Scientiarum Hungariae,* 16, 3-64.

Makkay, J., 1978. A Szegvár-tűzkövesi *újkőkori* férfi-szobor *és a 'Föld és Ég* elválasztásának' *ősi* mitosza [The Neolithic male figurine from Szegvár-Tűzköves and the ancient myth of the separation of Heaven and Earth]. *Archaeologiai Értesítő,* 103, 164-183.

Makkay, J., 1979. The Late Neolithic male statuette of Szegvár and the ancient myth of the Separation of Heaven and Earth. *Acta Archaeologica Academiae Scientiarum Hungariae,* 27, 1-38.

Makkay, J., 1982a. *A magyarországi neolitikum kutatásának új eredményei.* Budapest: Akadémia Kiadó.

Makkay, J., 1982b. Some comments on the settlement patterns of the Alföld Linear pottery. *In:* B. Chropovský, ed. *Siedlungen der Kultur mit Linearkeramik in Europa.* Nitra: Archäologisches Institut der Slowakischen Akademie der Wissenschaften, 157-166.

Makkay, J., 2004. *Tellek, tételek, istenek. Vonzások és választások a Két folyó köze és az Alföld között,* Tracta Minuscula 38. Budapest (self-published).

Makkay, J., 2005. *Újkőkori* teogónia. Agyagból mintázni istent *és* embert [Neolithic theogony: clay images of gods and men]. *In:* L. Bende and G. Lőrinczy, eds. *Hétköznapok vénuszai. Tanulmánykötet a Hódmezővásárhelyi Tornyai János Múzeum állandó régészeti kiállításának megnyitása alkalmából.* Hódmezővásárhely: Csongrád Megyei *Önkormányzat* Múzeuma, 85-121.

Milojčić, V., 1949. *Chronologie der jüngeren Steinzeit Mittel- und Südosteuropas.* Berlin: Gebrüder Mann.

Móra, F., 1925. A csókai *őstelepről* [Csokaer (*Čoka*) Fund aus der Urzeit]. *Dolgozatok,* 1, 18-25.

Müller-Karpe, H., 1968. *Handbuch der Vorgeschichte. Bd. II: Jungsteinzeit.* München: C.H. Beck'sche Verlagsbuchhandlung.

Osztás, A., Zalai-Gaál, I., Bánffy, E., Marton, T., Nyerges, É.Á., Köhler, K., Somogyi, K., Gallina, Zs., Ramsey C.B., Dunbar, E., Kromer, B., Bayliss, A., Hamilton, D.,

Marshall, P., Whittle, A.W.R., 2016. Coalescent community at Alsónyék: the timings and duration of Lengyel burials and settlement. *Bericht der Römisch-Germanischen Kommission,* 94 2013 (2016), 180-282.
Palaguta, I.V., 2018. 'Group portrait' of the early agricultural era: a set of figurines of Vinča culture from Stubline (Serbia) in the context of the European Neolithic and Copper Age societies. *Вестник СПбГУ. Искусствоведение,* 8 (4), 626-645.
Parkinson, W.A., 2006. *The social organization of Early Copper Age tribes on the Great Hungarian Plain.* BAR International Series 1573, Oxford: Archeopress.
Pétrequin, P., Cassen, S., Errera, M., Tsonev, T., Dimitrov, K., Klassen, L., Mitkova, R., 2012. Les haches en 'jades alpins' en Bulgarie (Axeheads of 'Alpine jade' in Bulgaria). *In:* P. Pétrequin, S. Cassen, M. Errera, L. Klassen, A. Sheridan, A.M. Pétrequin, eds. *Jade : grandes haches alpines du Néolithique européen.* Besançon: Presses Universitaires de Franche-Comté, 46-183.
Piggott, S., 1965. *Ancient Europe*. Edinburgh: Edinburgh University Press.
Raczky, P. and Sebők, K., 2014. The outset of Polgár-Csőszhalom tell and the archaeological context of a special central building. *In:* S. Forţiu and A. Cîntar, eds. *ARCHEOVEST II/1. In Honorem Gheorghe Lazarovici Interdisciplinaritate în Arheologie*. Szeged: JATE Press, 51-100.
Raczky, P., Domboróczki, L., Hajdú, Zs., 2007. The site of Polgár-Csőszhalom and its cultural and chronological connections with the Lengyel culture. *In:* J.K. Kozłowski and P. Raczky, eds. *The Lengyel, Polgár and related culture in the Middle/Late Neolithic in central Europe.* Kraków: Polska Akademia Umiętności, 49-70.
Raczky, P., Füzesi, A., Rassmann, K., Bánffy, E., 2021. *Újkőkori* települési halmok Hódmezővásárhely környékén. *In:* V. Csányi, ed. *Korok, kultúrák, lelőhelyek*. Hódmezővásárhely: Tornyai János Múzeum, 7-26.
Renfrew, C., 1973. *Before civilization: the radiocarbon revolution and prehistoric Europe*. London: Jonathan Cape.
Renfrew, C., 1978. Varna and the social context of early metallurgy. *Antiquity,* 52, 199-203.
Rezi-Kató, G., 2009. Szegvár-Tűzköves, vagy ami megmaradt… [Szegvár-Tűzköves, or what remains…] *In:* L. Bende and G. Lőrinczy, eds. *Medinától Etéig. Régészeti tanulmányok Csalog József születésének 100. évfordulójára*. Szentes: Koszta *József* Múzeum, 91-97.
Schachermeyr, F., 1953-54. *Dimini und die Bandkeramik*. Mitteilungen der Anthropologischen Gesellschaft 83. Wien: Ferdinand Berger.
Seleanu, M., 2014. *A Szegvár-tűzkövesi neolitikus telepen 1978-ban végzett ásatás leletei és tanulságai.* Unpublished master's thesis, Eötvös Loránd University, Budapest, 1981, reworked and edited by T. Horváth. Budapest (self-published).
Sherratt, A., 1983. The development of Neolithic and Copper Age settlement in the Great Hungarian Plain. *Oxford Journal of Archaeology,* 1(3), 287-316.
Siklósi, Zs., 2013. *Traces of social inequality during the Late Neolithic in the eastern Carpathian Basin*. Dissertationes Pannonicae IV/3. Budapest: L'Harmattan.
Sørensen, L., Pétrequin, P., Pétrequin, A.-M., Errera, M., Horejs, B., Herbaut, F., 2017. Les limites sud-orientales des jades alpins (Grèce et Turquie) [The south-eastern limits of Alpine jades (Greece and Turkey)]. *In:* P. Pétrequin, E. Gauthier, A.-M., Pétrequin, eds. *Jade: objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique. Tome 3.1.* Besançon: Presses Universitaires de Franche-Comté, 491-520.
Spasić, M., 2014. A group find of Neolithic figurines of the Vinča culture from Stubline, Serbia. *Les Carnets de l'ACoSt,* 12, 1-6. DOI: 10.4000/acost.217
Thomas, J., 2015. Commentary: what do we mean by 'Neolithic societies'? *In:* C. Fowler, J. Harding, D. Hofmann, eds. *The Oxford handbook of Neolithic Europe*. Oxford: Oxford University Press, 1073-1091.

Tompa, F., 1937. 25 Jahre Urgeschichtsforschung in Ungarn 1912-1936. *Bericht der Römisch-Germanischen Kommission,* 24-25 1934-1935 (1937), 27-127.

Tringham, R., 1971. *Hunters, fishers and farmers of eastern Europe 6000-3000 BC*. London: Hutchinson and Co.

Trogmayer, O., 1990. Der Gott mit Axt. Gedanken zu einem neuen Statuettefund (Statuette V). *In:* W. Meier-Arendt, ed. *Alltag und Religion. Jungsteinzeit in Ost-Ungarn. Ausgrabungen in Hódmezővásárhely-Gorzsa, Szegvár-Tűzköves, Öcsöd-Kováshalom, Vésztő-Mágor, Berettyóújfalu-Herpály*. Frankfurt am Main: Museum für Vor- und Frühgeschichte, 66-69.

Trogmayer, O., 1991. Le dieu à la hache : réflexions sur une statuette découverte récemment (Figurine V). *In:* M. Jannet-Vallat, ed. *Les agriculteurs de la Grande Plaine Hongroise (4000-3500 av. J.-C.).* Budapest: Kossuth Press, 64-67.

Whittle, A.W.R., 1996. *Europe in the Neolithic: the creation of new worlds,* Cambridge World Archaeology. Cambridge: Cambridge University Press.

Whittle, A.W.R., 2018. *The times of their lives: hunting history in the archaeology of Neolithic Europe.* Oxford and Philadelphia: Oxbow.

Zalai-Gaál, I., 2002. Das 'prähistorische Modell von Varna' und die Fragen der Sozialstruktur der Lengyel-Kultur. *Acta Archaeologica Academiae Scientiarum Hungariae,* 53 (4), 273-298.

Zalai-Gaál, I. and Osztás, A., 2009. A lengyeli kultúra települése *és* temetője Alsónyék-Kanizsa-dűlőben. *In:* L. Bende and G. Lőrinczy, eds. *Medinától Etéig. Régészeti tanulmányok Csalog József születésének 100. évfordulójára*. Szentes: Koszta József Múzeum, 245-254.

Zalai-Gaál, I., Gál, E., Köhler, K., Osztás, A., Szilágyi, K., 2012b. Präliminarien zur Sozialarchäologie des lengyelzeitlichen Gräberfeldes von Alsónyék-Bátaszék, Südtransdanubien. *Praehistorische Zeitschrift,* 87 (1), 58-82.

Zalai-Gaál, I., Köhler, K., Osztás, A., 2012a. Totenbrett oder Totenhütte? Zur Struktur der Gräber der Lengyel Kultur mit Pfostenstellung in Südtransdanubien. *Acta Archaeologica Academiae Scientiarum Hungaricae,* 63, 69-116.

Yerkes, R.W., Gyucha, A., Parkinson, W.A., 2009. A multiscalar approach to modeling the end of the Neolithic on the Great Hungarian Plain using calibrated radiocarbon dates. *Radiocarbon,* 51 (3), 1071-1109.

PART 2. SOCIAL TRANSFORMATIONS AND INEQUALITIES

Social transformations of liminal areas in the Late Neolithic: A multidisciplinary approach to the site of Gradište (Serbia)

Miroslav Marić, Silvia Amicone, Jelena Bulatović, Nemanja Marković, Neda Mirković Marić

Abstract

The site of Gradište, located near the town of Kikinda, in the Serbian part of the Banat region, has been the subject of multidisciplinary archaeological research since 2014, focusing on the formation and transformation of human societies between the Neolithic and the Late Bronze Age, human – landscape interactions, local area networks, communications, and trade and exchange in a liminal area constantly washed by influences of major traditions originating both in the Balkans and in the Carpathian Basin. The site was occupied between the late 6th and the 1st millennium BC and encompasses a large area of diverse traces of human activities, illustrating its varying use through time. In our efforts to elucidate the origins, development and transformations of the local Late Neolithic population, we use a multidisciplinary approach to the material culture remains, Bayesian chronological dating of events, and scientific analysis of period proxy data. The approached showed significant alterations to material culture and societal organisation through time, from the settlement organisation and architecture building to pottery making and firing, to subsistence adaptation to local environment.

Keywords: *Neolithic, Banat, Vinča, Linear Pottery period, Gradište, archaeology of liminal areas, small telloid settlements*

Introduction

The site of Gradište is located approximately halfway between the town of Kikinda and the village of Iđoš, in the north-east Serbian region of Banat. The area is situated in the south-eastern part of the Basin, between the valleys of the Tisza (also spelled

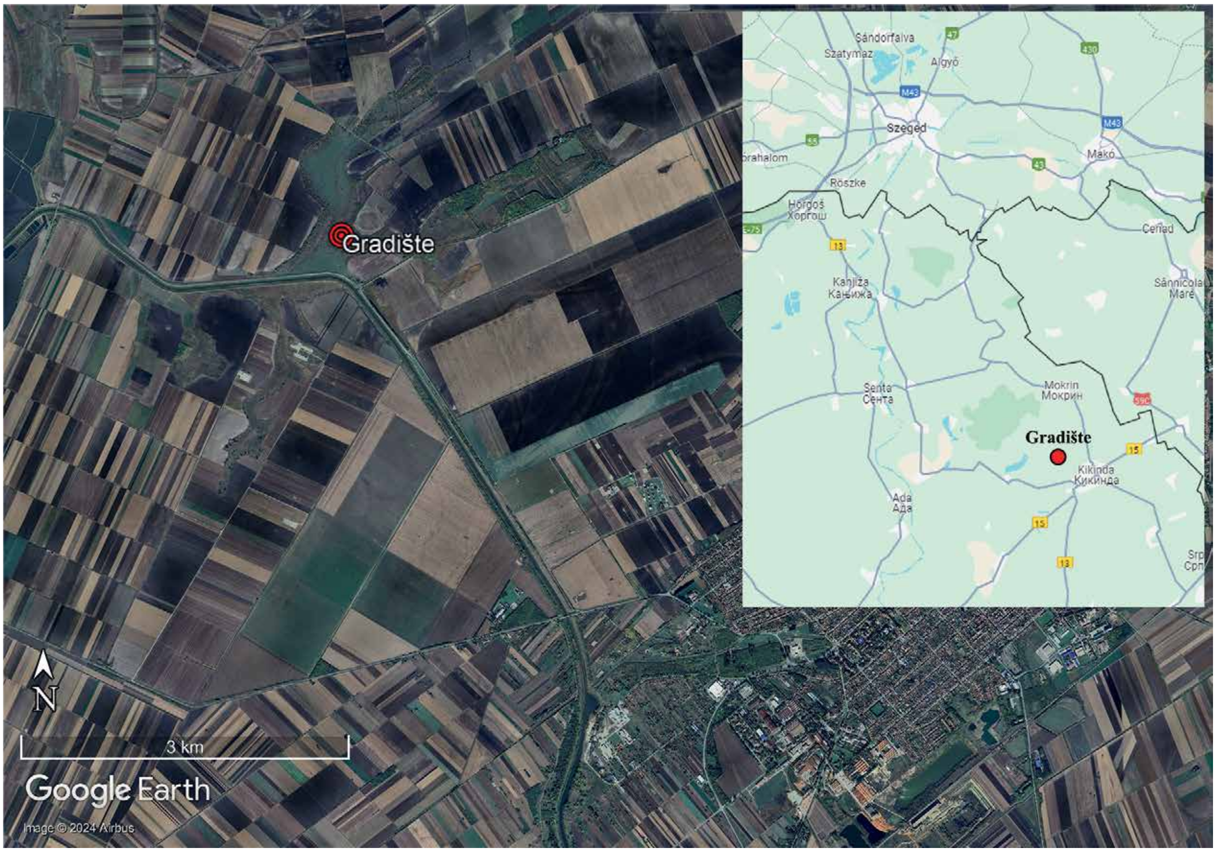

Figure 1. Gradište. Location of the site near the city of Kikinda, Serbia.

Tisa) to the west, the Mureș (Hungarian: Maros) to the north, and the Begej (Serbian: Бегеј; Hungarian: Béga, Kistemes; Romanian: Bega) to the south. These valleys were the major transit arteries in prehistory that were instrumental in forming settlement locations, spheres of influence and relationships (O'Shea 2011; Marić and Mirković-Marić 2020). It is located on the edge of a terrace formed by the Pleistocene meandering of the River Tisza (Fig. 1), above the confluence of two local streams, the Grčka and the Berčula, which drained into the now-abandoned meander of the Tisza near the village of Idjoš (Marić *et al.* 2016).

The terrace gradually widens from the south-west towards the north-east between the two local streams. The archaeological evidence shows it to be first settled in Middle Neolithic Starčevo – Körös period, but the main parts of the settlement belong to the Late Neolithic Vinča – Tisza period and to the transition period between the Middle and Late Bronze Age, the Belegiš I-II period (Molloy *et al.* 2020).

The site has been archaeologically explored several times since its discovery at the beginning of the 20th century, first by Gyula Kisléghi Nagy, in 1913. His only recently discovered diary covers the period up to 1909 (Lőrinczy 2010), and it is unknown what research he carried out after that. After the Second World War, work was resumed on the site by Miodrag Grbić, who conducted two seasons of excavations, in 1947 and 1948, primarily focused on the Bronze Age circular enclosure to the north-east of the Neolithic settlement. In his reports, Grbić (1950, 1951) notes sporadic finds of Neolithic pottery. A year later, in 1949, Luka Nadlački sectioned the Bronze Age earthen rampart, in the process discovering a Neolithic burial, although this find cannot be relocated today in the depot of the museum in Kikinda. Five years later, in 1954, Nadlački undertook small-scale excavations of the Neolithic mound at the very south of Gradište and discovered a daub structure with both Tisza and Vinča pottery production material in situ (Girić 1957). During

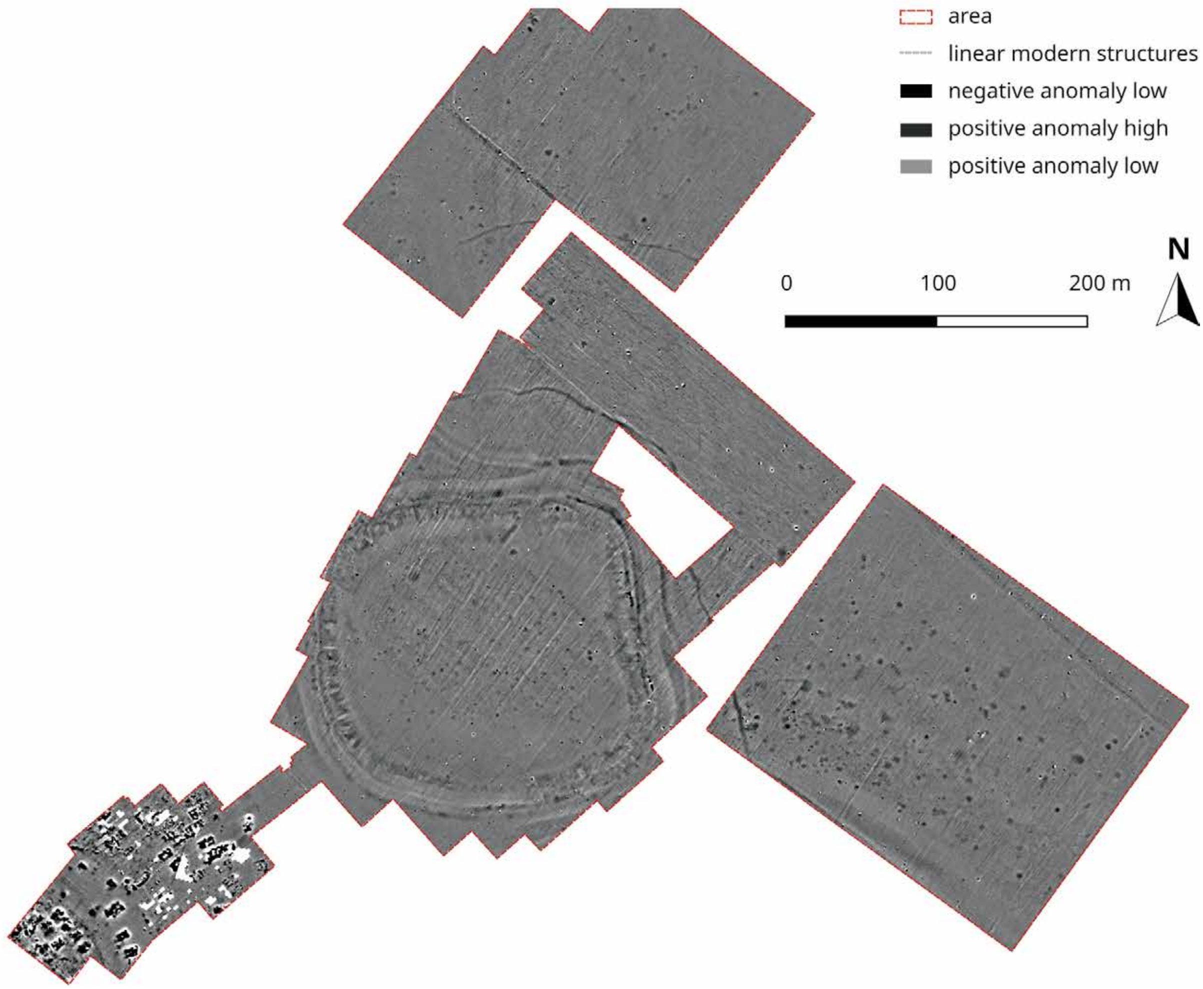

Figure 2. Gradište. Results of the geophysical survey.

the construction of the Great Kikinda Channel, small-scale rescue excavations were undertaken in 1972, by the Provincial Institute for Heritage Protection of Cultural Monuments. No new complete daub structures were discovered, only a partially preserved daub floor, and the results were never published.

In 2014, a new project was undertaken on the site (Marić *et al.* 2016), aimed at exploring three key phases, the Early – Middle Neolithic, Middle – Late Neolithic and the Middle – Late Bronze Age, focused on three main issues: the first farmers, emerging complexity and centralisation, and stratification and migration. In the first two seasons of the campaign, a geophysical survey of 18 ha of the site area was performed (Fig. 2), accompanied by non-systematic surface collection, which identified several areas of interest.

Although the location of the Neolithic settlement at the south-western tip of the terrace was already known from previous research, the discovery of Middle Neolithic Starčevo – Körös fragments in the north-eastern section was a surprise, as these were located a mere 600 m as the crow flies from the Starčevo type site, which dates to the same period. Systematic surveys in the immediate area since (Nikolić 2020) have detected 43 Neolithic settlements, 39 of which belong to the Starčevo – Körös period and 4 to the Vinča, or Tisza Late Neolithic, but the vast majority of discovered sites are separated by greater distances than this.

Here we present preliminary results of the research of our ongoing project conducted between 2015 and 2021, reflecting on possible evidence of social

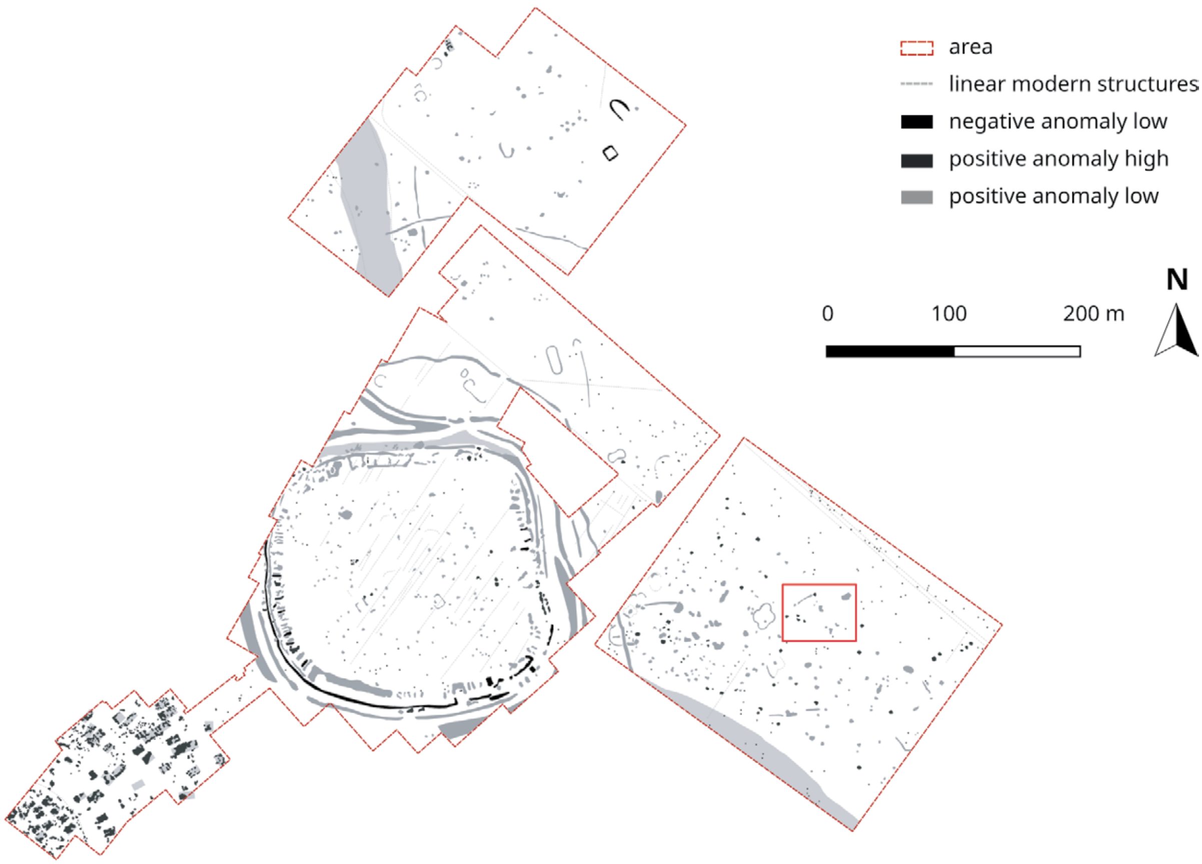

Figure 3. Gradište. Location of the Starčevo – Körös features in the north-eastern section of the site (solid rectangle).

transformations occurring in liminal areas bounded by core territories of major cultural and technological complexes of the Late Neolithic. We attempt to define domestic practices and compare them with the core areas farther away and see their influence through time.

The settlement

The geophysical survey conducted in the fall of 2014, 2015 and 2021 revealed subsurface archaeological evidence in an area close to 21 ha in size. However, only approximately 1.2 ha of the Late Neolithic portion of the site was covered during the survey due to the terrain being covered with thick wild vegetation. Field measurements and estimates put the possible size of the settlement at 2.5 ha, thus enabling a relatively precise reconstruction of its appearance during the Late Neolithic. The discovery of Starčevo – Körös material east of the Bronze Age enclosure with earthen wall presents us with a unique overview of the early phase of Neolithic life in this area.

The area with the finds of the Starčevo – Körös period, approximately 40 × 50 m in size, is located on a central part of the eastern edge of the Pleistocene terrace, immediately to the east of the Bronze Age enclosure (Fig. 3, red square).

The geophysical imaging revealed several circular and sub-oval features that appear to be grouped in a circular pattern around a central feature. Since the collected Early Neolithic material originates exclusively from this area of that particular field, it is most likely that these features all belong to the same period (Fig. 4).

The circular arrangement of features is not unknown in the Starčevo core. Examples from Starčevo tradition settlements exist on several excavated sites,

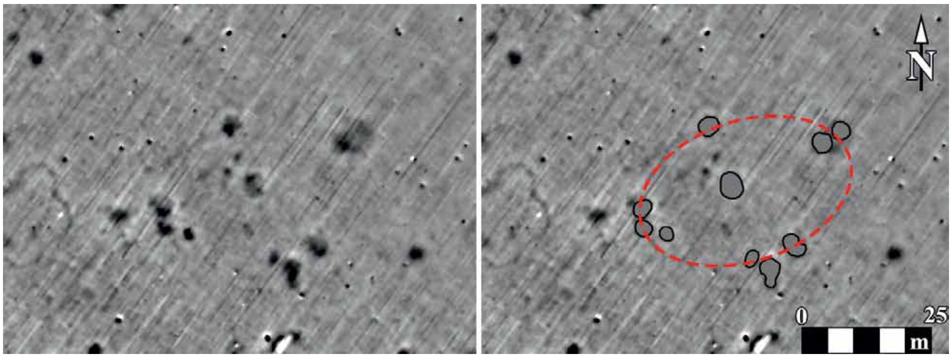

Figure 4. Gradište. Detail of the geophysical survey of the north-eastern section of the site, with the Starčevo – Körös features.

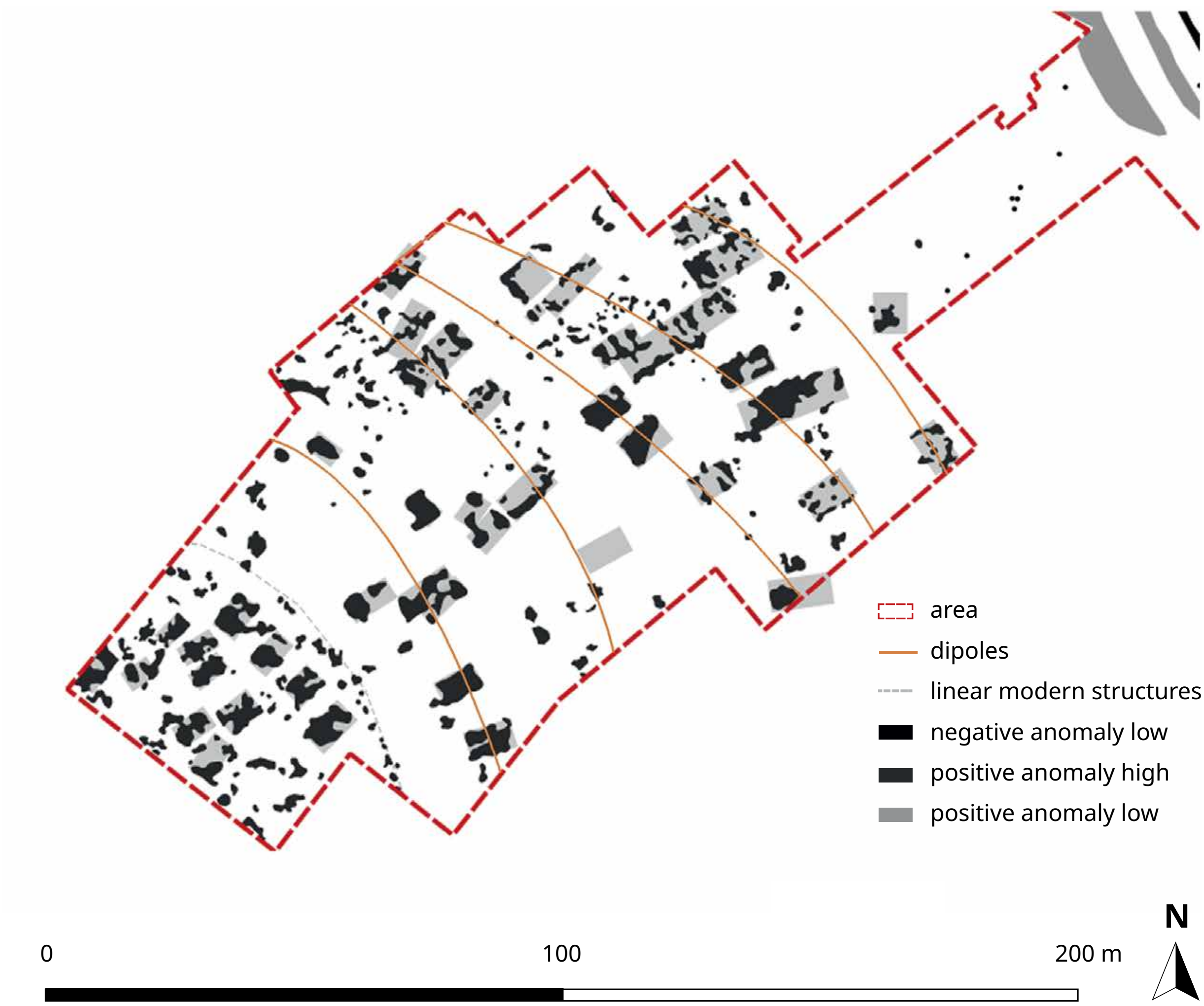

Figure 5. Gradište. Geophysical survey and interpretation of the measurements of the Late Neolithic settlement.

including Belo Brdo, in Vinča (Vasić 1936, Plates VI-VII); Blagotin, near Trstenik (Stanković 1992); and Jaričište, near Lajkovac (Marić 2013, Fig. 2), while to a significantly lesser degree, they exist in the Körös area, on such sites as Szolnok-Szanda (Raczky 2012, Fig. 3.3) and Maroslele-Pana (Paluch 2012, Figs. 4; 37). However, it appears that a circular disposition of features is not the predominant type of organisation within Starčevo – Körös settlements; instead, a linear or clustered disposition is preferred (*e.g.* Minichreiter 1998, Fig. 11; Makkay *et al.* 2007; Bánffy *et al.* 2010, Fig. 1). Could the cluster of features at Gradište represent an example of dwelling organisation at the level of a nuclear family?

The size of individual structures in this cluster does not differ significantly, at least as estimated from the size of the geophysical anomalies recorded. However, without an archaeological excavation, it is impossible to obtain precise measurements and establish a possible baseline for the rest of the cluster. Still, since most of the Starčevo – Körös period settlements in the region (Trifunović 2012, 2016, 2020) do not appear to be very large in size either, perhaps this cluster of features is evidence of a specific settlement pattern, characteristic only for this region, with small-scale individual or extended households or homesteads positioned in close proximity to each other, rather than being clustered into larger settlements.

The geophysical survey of the Late Neolithic settlement provided a different picture, with close to 40 rectangular geomagnetic features easily identifiable in the image of the surveyed area (Fig. 5). On the assumption that a similar feature density should be present in the unsurveyed area, we expect between 80 and 90 rectangular features to be present in the Late Neolithic settlement overall.

Several publications compare the disposition of features among sites of the same period in the region, including the site of Borđoš, a geophysically surveyed site on the immediate riverbank of the present-day course of the River Tisza 42 km south-west of Gradište. This tell site, located south of the town of Novi Bečej, is a significantly larger, multiperiod settlement (Hofmann *et al.* 2020) with a Late Neolithic component, and its settlement organisation appears to be different as well. At Borđoš, the tell (itself three times larger than the estimated size of Late Neolithic Gradište) is separated from the rest of the settlement by a dual ditch system. The flat settlement to the south-west of Neolithic Borđoš has multiple ditch systems around it as well, a feature that could not be identified at Gradište. The lack of an outer ditch around Late Neolithic Gradište settlement on geophysical survey results can be attributed to the later construction of the Bronze Age enclosure with earthen ramparts to the north-east, which most likely negated it in process.

Approximately 50 km to the south-east of Idjoš lies the site of Uivar (Schier 2008, 2014; Draşovean and Schier 2020), another Late Neolithic (and Early Copper Age) settlement. A geomagnetic survey of the site (Schier 2014, Fig. 6), which, at 3 ha, is slightly larger than Gradište, shows a somewhat different settlement layout, with a system of concentric enclosure ditches constructed sequentially over longer periods of site occupation within which structures appear to be arranged centripetally. Farther south, in the core Vinča area, other examples exist. Oreškovica Selište is another example of a circular, enclosed settlement, about 6 ha in size, surrounded by multiple ditches (Borić *et al.* 2018, Fig. 2). The site of Stubline (Crnobrnja 2012, Fig. 2; 3) is similar to Oreškovica Selište, but, at 12 ha, significantly larger. Additional examples of different settlement organisations can be found elsewhere in the Vinča area, including at Belovode (Rassmann *et al.* 2021a, Fig. 10) and Pločnik (Rassmann *et al.* 2021b, Fig. 7), but these settlements are all extremely large and are obviously more complex than Gradište.

Looking towards the north, in the Linearbandkeramik (LBK; Linear Pottery) area, more examples of settlement organisation from the period can be found, at such sites as Szeghalom-Kovácshalom and Vésztő-Mágor, some 130 km north of Gradište (Gyucha *et al.* 2015; Parkinson *et al.* 2018), which appear to be organised differently than Gradište, or the site of Szentpéterszeg-Kovadomb (Raczky and Anders 2014, Fig. 3), which though somewhat more extensive than Gradište, appears similar in the organisation, despite being 170 km distant.

There are also additional differences among the sites, namely the disposition of structures in the tell *vs.* the flat area. While at Borđoš the tell structures appear to be spaced apart and not organised in rows, the opposite occurs at Gradište. Here the tell area is densely packed with structures arranged in dense rows and the flat area of the settlement is more spaced apart with structures that appear clustered. A similar row organisation can also be seen at Stubline (Crnobrnja 2012), Oreškovica (Borić

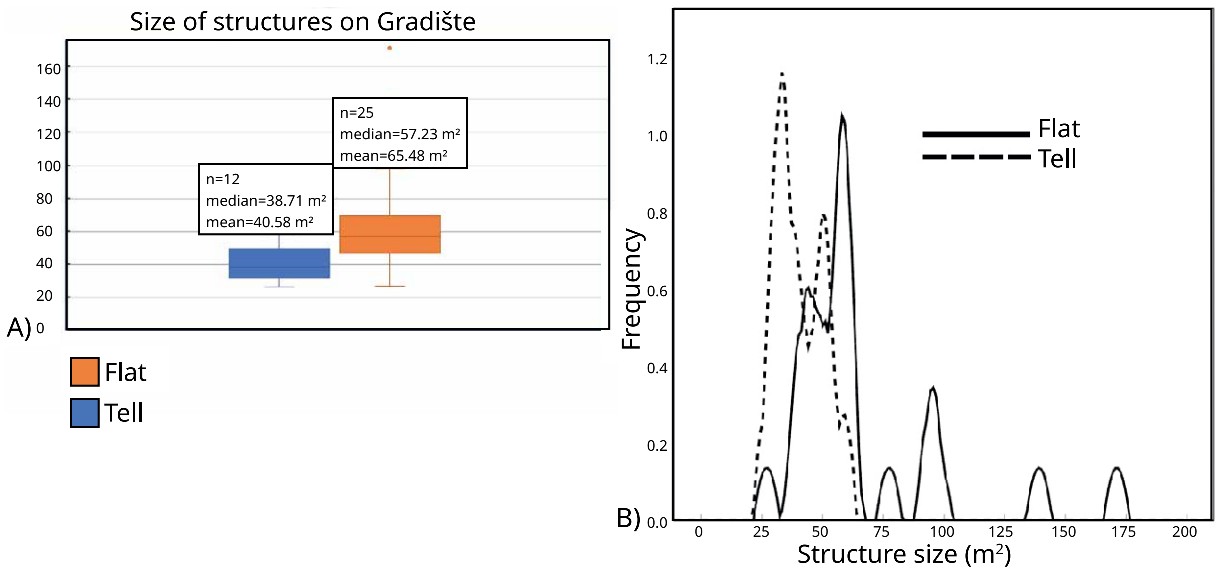

Figure 6. Gradište. Mean and median size of wattle-and-daub structures (A) and kernel density estimation of the structure surface (B).

et al. 2018), and Belovode (Rassmann *et al.* 2021), while clustering is detectable at Pločnik (Rassmann *et al.* 2021) and at some LBK sites (Raczky and Anders 2014, Fig. 3; Gyucha *et al.* 2015, Fig. 5; 6).

Not only the settlement organisation, but also the size of the linear structures varies significantly. For instance, at Borđoš (Hofmann *et al.* 2020, Fig. 4), the estimated mean size of the structures on the tell is 47.8 m^2 and that in the flat area is 61-71 m^2. At Stubline, the estimated mean value for the whole site is 58.3 m^2 (Crnobrnja 2012, 158), whereas at Belovode, it is 52.6 and at Pločnik it is 56.2 m^2 (Rassmann *et al.* 2021, 275). The estimated mean size of structures on the Gradište is estimated at 40.58 m^2 for the tell and 65.48 m^2 for the flat area (Fig. 6.A), putting the values much closer to those of Borđoš than those of the more southern sites. The KDE of the structure surface at Gradište shows another difference: the existence of outliers of extreme size in the flat part of the site, where certain anomalies measure more than 170 m^2 (Fig. 6.B).

While complex, large structures are known to exist in the LBK area (Horváth 1987, 1989), their function is often hard to interpret. Such supersized, complex structures are less known in the Vinča culture core area, where, with some exceptions (*e.g.* Bogdanović 1988; Marić 2010; Tripković 2013, Fig. 18), they are mostly limited to rectangular, occasionally multiroom, structures well under 100 m^2 in size.

Settlement development and organisation through time

Research on the intra-settlement organisation at Gradište provides clues to transformations in intra-settlement organisation through time in both the flat and the tell part of the site. Single-context recording of excavation enabled the definition of at least four occupation phases in the flat part of the settlement (Fig. 7) and at least six occupation phases on the tell thus far (the tell excavations are still ongoing and have yet to reach the oldest layers, belonging to the Starčevo – Körös period).

Based on the relative stratigraphy thus far, a Bayesian statistical model was devised to produce a complete chronological sequence of the site (Fig. 8).

Combined, these data illustrate the transformation of the site over time, from an initial settlement consisting of dug-in structures (Fig. 9B); to early rectangular wattle-and-daub structures; and, in the final phase (Fig. 9D), the multi-roomed

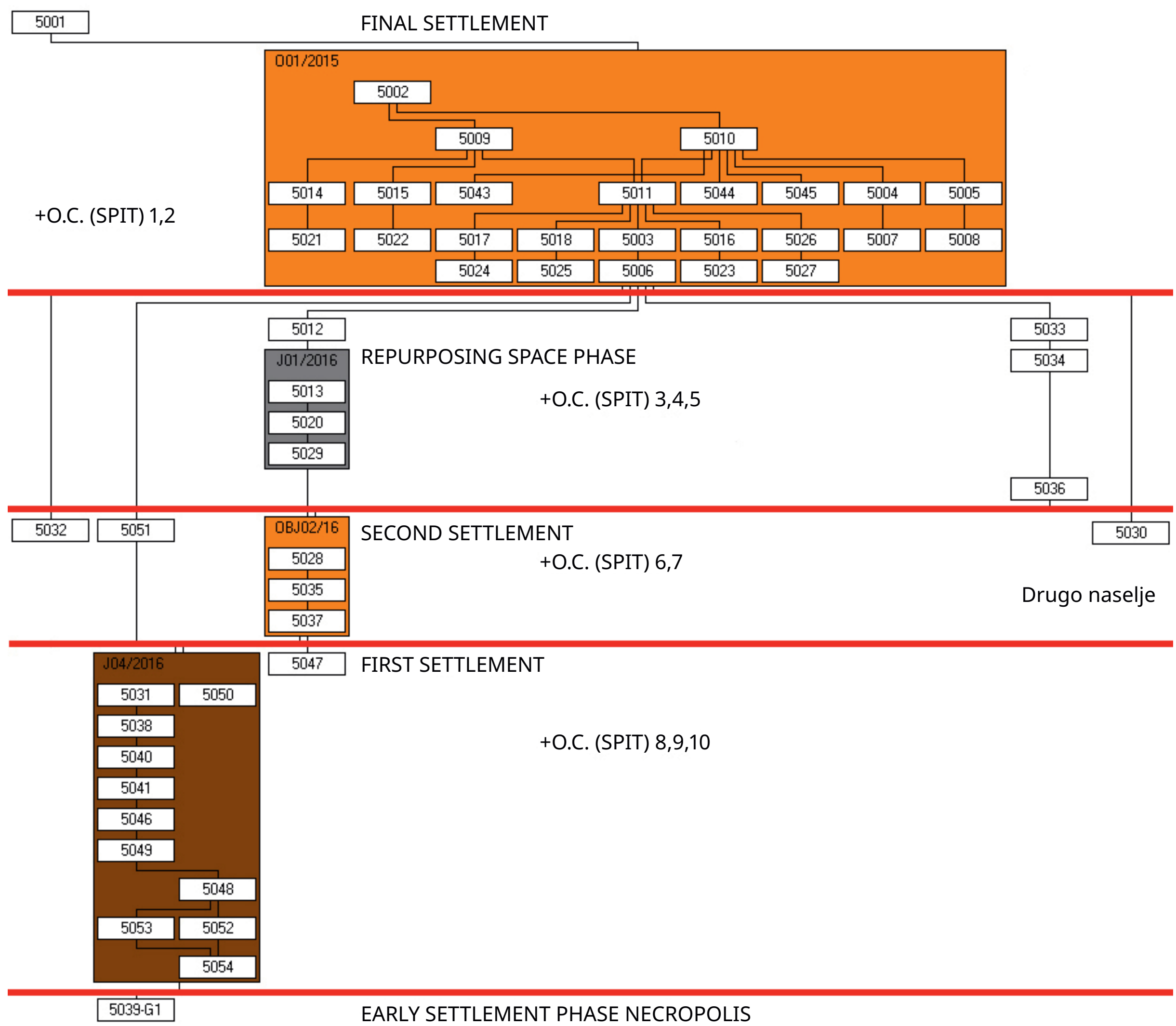

Figure. 7. Gradište. Simplified relative stratigraphy model of the features in Trench 5, in the flat settlement.

wattle-and-daub structures. The modelled chronological sequence illustrates that the earliest occupation of the Late Neolithic settlement began on the tell, at 5221 (95.4% probability) 5081 BCE, possibly 5181 (68.3% probability) 5104 BCE, with the construction of dug-in structures as the earliest occupation phase of the tell (Occupation Phase [OP] 1). Somewhat later radiocarbon dates put the creation of the early phase necropolis (Fig. 9.A) at the very edge of the tell area (Grave 1/16, found in Trench 5) to 5128 (95.4% probability) 5052 BCE, possibly 5107 (68.3% probability) 5061 BCE).

The next phase of the tell settlement, consisting of a single, burnt wattle-and-daub structure found in Trench 8 (OP 2), has not yet been radiocarbon dated at the time of writing, and despite our best efforts, we cannot place it in its exact absolute chronological position. However, the occupation phase directly above it, consisting of two wattle-and-daub structures (one burnt and only partially excavated, as it extended outside the trench limits, the other unburnt and examined in full) is radiocarbon dated (OP 3). These structures chronologically appear to be contemporary with the expansion of the settlement outside the tell boundaries, at 5052 (95.4% probability) 5002 BCE, possibly 5042 (68.3% probability) 5017 BCE, as the dating of the first phase of the flat settlement, a dug-in in Trench 5, is modelled at 5065 (95.4% probability) 5016 BCE, possibly 5054 (68.3% probability) 5030 BCE. The expansion is also accompanied by the cutting of the early trench at

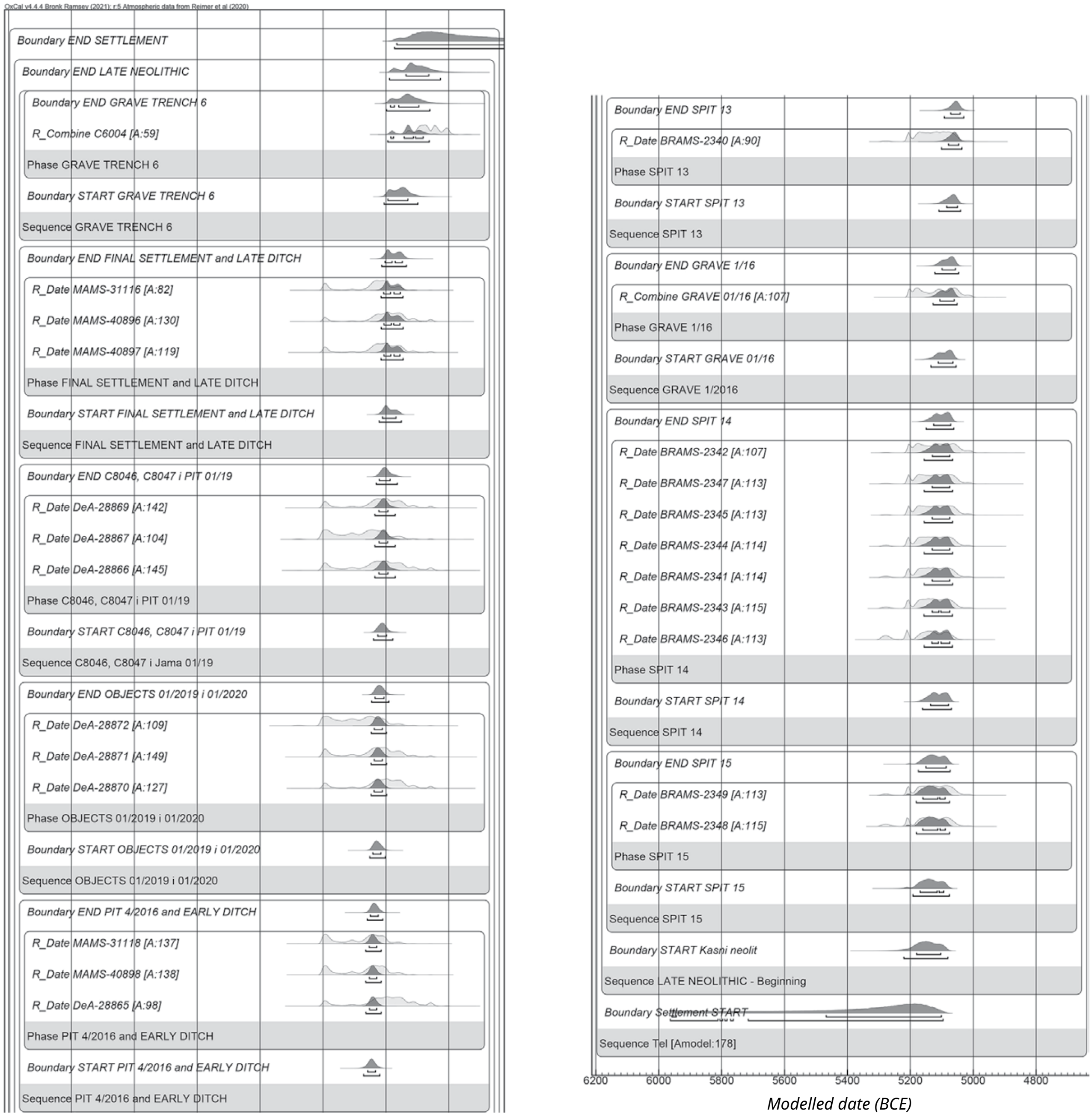

Figure 8. Gradište. Probability distributions of the radiocarbon dates from the Bayesian model, developed based on the relative stratigraphy of the site. The posterior density estimates output of the models are shown in dark grey, and the unconstrained calibrated radiocarbon dates are shown in light grey outline.

the base of the tell, found in Trench 12 (Fig. 10), with a radiocarbon date for the cut modelled to 5065 (95.4% probability) 5016 BCE, possibly 5053 (68.3% probability) 5030 BCE. Whether the cutting of the ditch – 1.2 m wide and more than 1 metre deep, with clear traces of post holes for wooden beams found in it – around the tell area is a sign of uncertain times or just a demarcation line between old settlers and newcomers remains to be seen, but either way, it is a clear sign of a significant transformation in the life of the settlement. A further indication of this transformation is the appearance of the first LBK examples in the assemblage of the site, indicating a shift in influence from the southern, Vinča-style pottery area to the northern, LBK area.

Following this occupation horizon on the tell, an abrupt change occurs in the area previously occupied by wattle-and-daub structures. It is now used as

Figure 9. Gradište. Occupational levels in Trench 5, in the flat settlement. Early phase grave (A); early settlement expansion dug-in structure (B); occupation period 3 refuse pit (C); final settlement wattle-and-daub structure (D). Photos: M. Marić (Borderlands: ARISE project documentation).

a workspace of some kind, with one refuse pit (04/19) and two concentrations of freshly worked animal bones (contexts 8046 and 8047) mixed with pottery fragments (OP 4). Modelled radiocarbon dates give dates of 5040 (95.4% probability) 4979 BCE, possibly 5027 (68.3% probability) 4999 BCE, meaning that, like OP3, OP4 covered a short timespan (14-33 years for OP 3 and 12-27 years for OP 4). This occupation phase in the flat settlement is also marked by a change in use of space, with pit 01/16 (Fig. 9.C) being the only context of the phase.

The final settlement of the Late Neolithic OP 5 on both the tell and the flat settlement is marked by a total of three burnt wattle-and-daub structures, one on the tell (Fig. 11) and two in the flat settlement (Fig. 9.D, accompanied by a newly cut ditch surrounding the tell (context 12 002).

Figure 10. Gradište. Early tell settlement – phase ditch in Trench 12. View from the north-east after excavation. Photos: M. Marić (Borderlands: ARISE project documentation).

All these structures were detected at the contact zone of the ploughed field and the archaeological layers. The start of the occupation is radiocarbon dated to 5022 (95.4% probability) 4952 BCE, possibly 5012 (68.3% probability) 4969 BCE. The end of the occupation is radiocarbon dates to 5014 (95.4% probability) 4935 BCE, possibly 5003 (35.8% probability) 4981 BCE, or 4971 (32.5% probability) 4948 BCE at 68.3% probability. The two structures excavated in full (Objects 01/2015 and 01/2016) appear to be of similar size and disposition, with a clearly visible subdivision into two separate rooms in Object 01/2015. The structures appear to be constructed in the same manner, implying that the same population was involved in their construction. The poor state of preservation of the tell structure denies us the possibility of analysing its function to the same extent as the two structures in the flat settlement.

The cutting of a new ditch on the tell, different in size and appearance but still in approximately the same place, indicates another major spatial transformation of the settlement of the late phase. This trench is mostly barely 50 cm wide (extending to 65 cm at the widest part of the trench), and is very shallow, under 40 cm deep in most places. Unlike the early phase ditch, with its wider spaced postholes of larger diameter, this ditch has narrowly spaced postholes of smaller diameter, indicating that these postholes were used for posts forming a palisade wall of densely packed vertical timbers. In this sense, this palisade is perhaps more of a boundary of the tell space rather than the defensive structure that has been inferred for the early phase ditch. Its placement overtops the early phase ditch indicates an awareness

Figure 11. Gradište. Final tell occupational phase (OP 5) wattle-and-daub structure, heavily damaged by post-depositional processes. View from the north-west. Photos: M. Marić (Borderlands:ARISE project documentation).

of the historic tell limits, retained over the centuries of occupation and the subsequent enlargement of the settlement that occurred in the process.

Finally, a chance find of an inhumation burial within the enclosed settlement of the Late Bronze Age, about 150 m away from the outermost Neolithic structures, gives us a clue to the possible location of a late phase necropolis, abutting the settlement on its north-east edge. An adult was placed on the back, with arms next to the body. The skeleton was radiocarbon dated to 4995 (95.4% probability) 4863 BCE, possibly 4943 (41.4% probability) 4913 BCE or 4907 (20.2% probability) 4882 BCE or 4985 (6.6% probability) 4976 BCE (68.3% probability), indicating a date 30 to 40 years later in the Late Neolithic period and hence a possibility of the existence of longer-lasting occupation than the settlement structures thus excavated show. Similar evidence exists from the nearby tell site of Gomilă, in Uivar (Schier 2014, 33), where a single structure in the western, outer part of the settlement provided evidence of Neolithic life post-dating the abandonment of the main settlement on the tell. Perhaps the late burial of the individual from the Late Neolithic grave at Gradište is evidence of a smaller population keeping the fire burning.

Material culture

The examination of the site assemblage is ongoing, in parallel with the excavations. Pottery, being the most numerous and most ubiquitous find on Neolithic sites in the region, is the obvious candidate for analyses that may provide evidence for social transformations at Gradište. In addition to typological and statistical analyses of the fragments and vessels, which showed the existence of typical Vinča-, hybrid Vinča – Tisza-, and typical Tisza-style pottery (Plate 1; 2), an integrated programme of scientific analysis has been applied to the ceramic materials from old excavations at Gradište (Mirković-Marić and Amicone 2019; Amicone *et al.* 2020; Amicone *et al.* 2021). These analyses include ceramic petrography to study the composition of the clay paste and scanning electron microscopy (SEM), as well as X-ray diffraction to study pyro technology (Maniatis and Tite 1981; Quinn 2013; Gliozzo 2020).

The material analysed via petrographic analysis (23 samples so far) comes from the settlement phase that is marked by Vinča- and Tisza-style assemblages (Vinča C, ca. 5000-4800 BCE).

Four fabrics have been recognised in the petrographic analysis (Mirković-Marić and Amicone 2019, Amicone, Mathur, *et al.* 2020). Fabrics A, B and C (Fig. 12) show a very similar mineralogical composition marked by feldspars, muscovite and

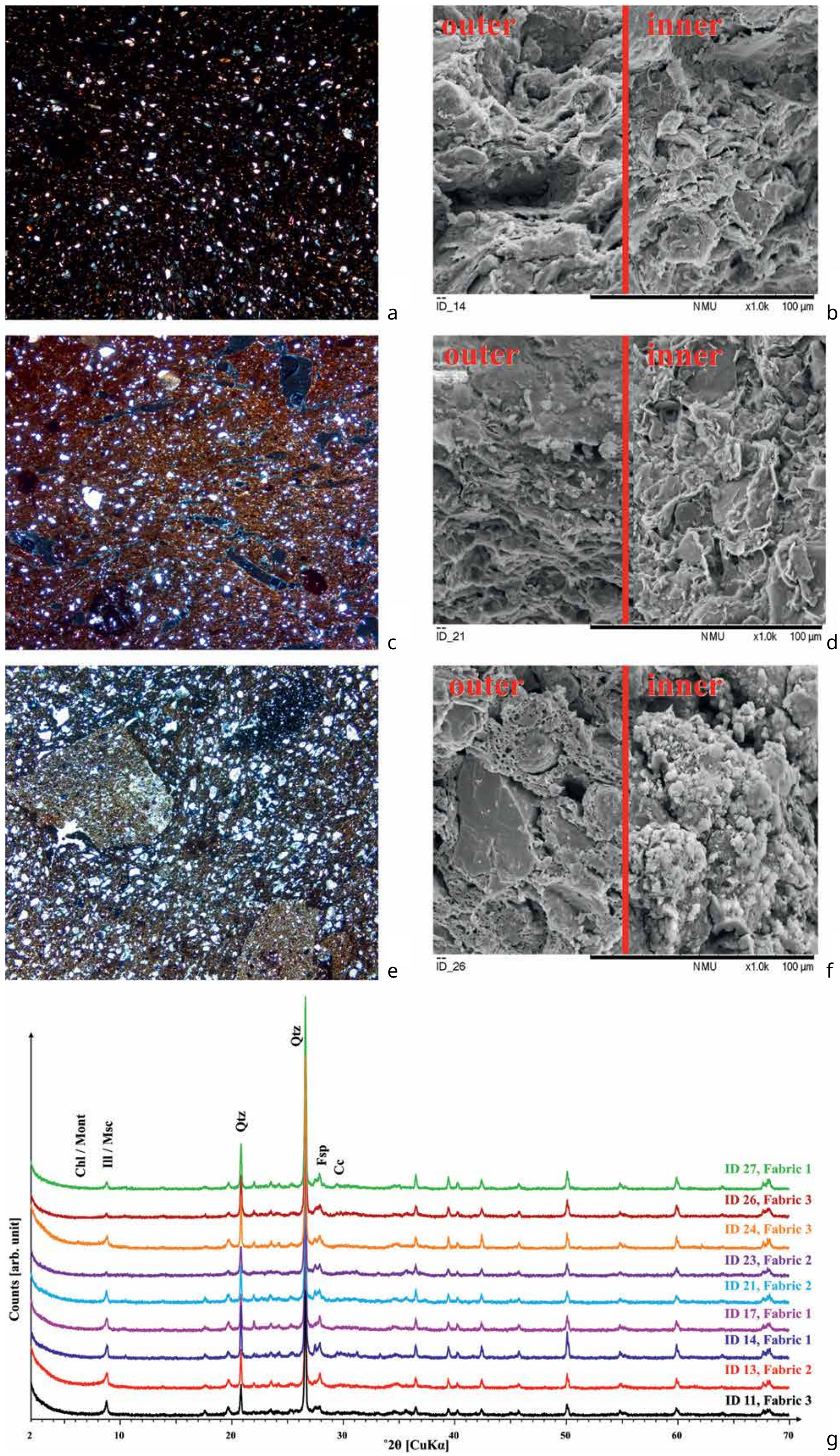

Figure 12. Gradište. Ceramic petrography micrographs (top row, left), scanning electron microscopy (SEM) micrographs (top row, right), and X-ray diffractograms (bottom row) of the three identified clay paste fabrics from the site: (a–b) Fabric A; (c–d) Fabric B; (e–f) Fabric C. Field of view for images (a), (c), and (e): 6 mm.

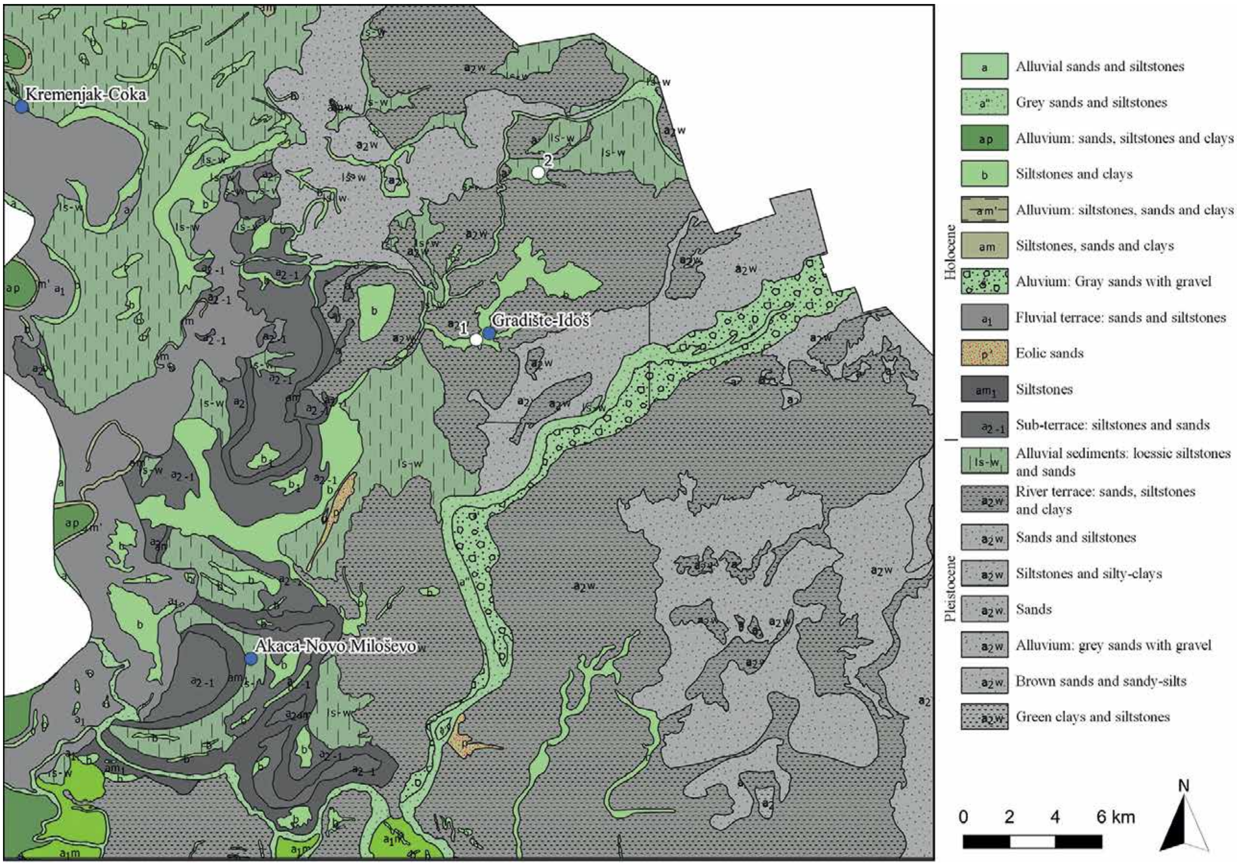

Figure 13. Gradište. Geological map of the surroundings of the site, with sampled clay outcrops marked with white dots and numerals.

less commonly amphibole and calcite. However, they differ in terms of grain-size distribution and tempering strategies.

Fabric A is very fine, suggesting this paste could have been produced with clay that had been cleaned via sieving or levigation prior to use, whereas fabrics B and C are coarser and are marked by plant and grog tempering, respectively. Analysis carried out on raw materials for pottery making available in the vicinity of the site of Gradište has shown that clays from the Pleistocene formations found not far from the site (Fig. 13) display close compositional similarity to the archaeological samples analysed (Amicone *et al.* 2021). This type of clay could have been selected and processed in different ways to produce the three types of paste identified in the pottery assemblage. Fabric A (fine) was used to make bowls (Vinča, Tisza or Vinča – Tisza hybrid), fabric B (plant material-tempered) was used to make Vinča lids and Tisza lids, and fabric C (grog-tempered) was especially used to make cooking vessels and sometimes to make Tisza lids. Overall, the samples so far analysed suggest that the various fabrics recognised at this site could related to different functions of the vessels rather than different material cultures (that is, Vinča Tisza). Ongoing analysis of ceramics from the recent (2015-2020) excavations and from phases attributed to the older occupation of this settlement (end of Vinča A/beginning of Vinča B) seems to suggest that the use of grog was already common at the site in the pre-Tisza phases.

Finally, fabric D (fabric 4 in Mirković-Marić and Amicone (2019)) is represented by only one sample (ID 23), and it is marked by tempering with igneous rock fragments, probably granodiorite (Fig. 14), which is not present in this region. This sample may therefore be an import (Mirković-Marić and Amicone 2019) from a region marked by the presence of intrusive igneous rocks, such as north-western Romania (Mount Bhor and Mount Apuseni).

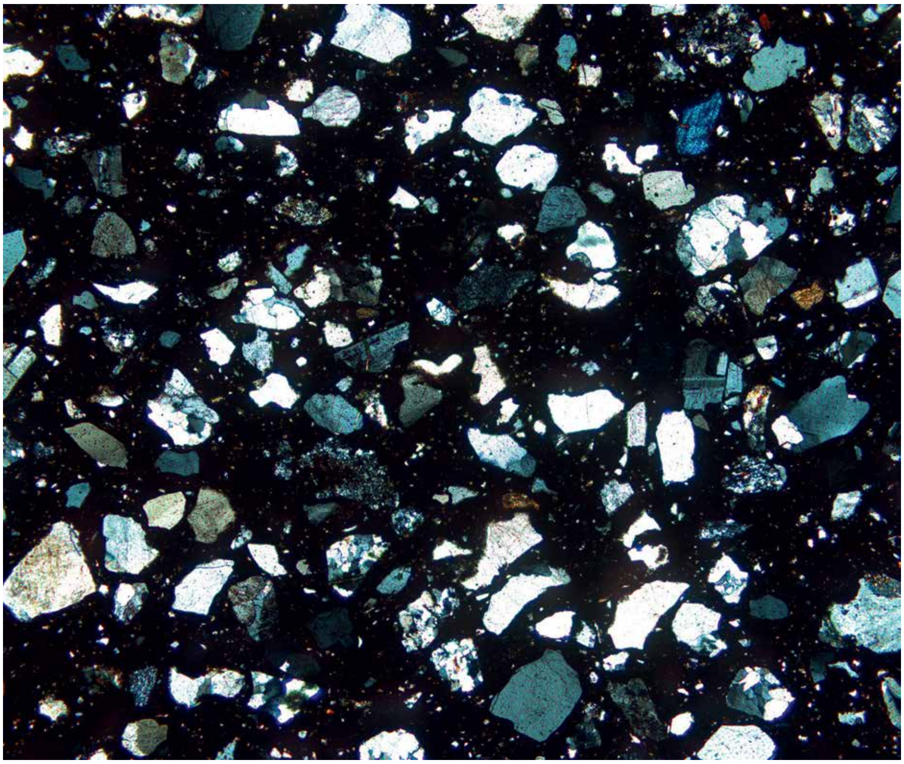

Figure 14. Gradište. Fabric D under the polarising microscope, showing temper composed of igneous rock fragments (XP). Field of view: 6 mm.

The pyrotechnological analysis carried out on nine samples representing the local fabrics (Fabrics A, B and C) shows that in many cases the pottery was fired at temperatures of less than 900º C, in a relatively fast process marked by slow heating and cooling rates (Amicone *et al.* 2020; Amicone *et al.* 2021). The colour of the archaeological samples indicates that firing took place in either oxidising conditions (Tisza-style vessels and cooking vessels) or reducing conditions which was applied to Vinča style vessels. The heterogeneous colour of the ceramic suggests that the potters were not always able to control the amount of oxygen reaching the vessels during firing. Experimental work using the Pleistocene clay sources mentioned above supports these interpretations and suggests that a pit or a simple updraft kiln may have been a possible pyrotechnological installation employed by these potters (Amicone *et al.* 2021).

The results of the scientific analysis carried out on the pottery from Gradište are in line with studies done on the ceramics from Vinča communities and, more broadly, with investigations into ceramic technology in the Neolithic and Chalcolithic in the Balkans (Kreiter *et al.* 2017; Spataro 2017, 2018; Amicone *et al.* 2019; Amicone, Mathur, *et al.* 2020; Amicone, Radivojević, *et al.* 2020; Koutouvaki *et al.* 2021). These studies suggest that the prehistoric communities of this region shared technological know-how that went beyond conventional material culture boundaries. Nevertheless, these studies also stress the existence of regional technological traditions, which are evident, for example, in the processing of raw materials and the relationship between fabric and vessel shapes (Spataro 2018). For instance, within Vinča material culture, there is huge variability in the types of tempers added to the clay paste by the potters. While landscape constraints undoubtedly influenced the choices of the producers, regional traditions likely influenced definition of the patterns observed in the various studies (Amicone, Mathur, *et al.* 2020). This is also true for the correlation between vessel type and fabric, an aspect often considered to be correlated to the emergence of craft specialisation (Santacreu 2014). At some Vinča sites, such as Pločnik, it is possible to exclude a close relationship between fabric and

shape. At this site, a minimally processed and un-tempered clay was used to produce the entire variety of pottery types present at the site. At other settlements, such as Gradište, it is possible to observe a specific way of processing clay (cleaning and tempering) according to the type of vessels being produced (Amicone, Mathur, *et al.* 2020).

Overall, this picture suggests the existence of diverse communities of practice, which share common technological traits that resonate over a large temporal and regional scale as well as regional characteristics that could reflect a different level of specialisation and could correspond to tighter learning networks, probably favoured by special propinquity (Amicone 2017). Ongoing analysis of ceramic samples from the recent excavations at Gradište that represent all the chronological phases and pottery technological variability will help to further elucidate ceramic technological development at this site from the Early Neolithic to the Chalcolithic and to give new insights into the complex interrelationships between Vinča and Tisza material cultures in this borderland region.

Archaeozoological evidence

Animal remains collected during the 2015-2020 excavation seasons at Gradište are presented here. The analysis of the faunal material recovered in 2021, which originate from the earliest OPs (OP 1 and part of OP 2) at the tell settlement, is currently ongoing. A total of 16 288 animal remains have been analysed for the current the study. The assemblage consists of remains of (micro- and macro) mammals, fish, birds, turtles, bivalves and snails. Around 52% of animal remains were collected on the tell, while the rest (48%) was found in the flat settlement. Out of the total tell settlement faunal assemblage (N=8339), 20.5% were identified to the taxonomic level of species or genus, while for the flat settlement faunal assemblage, that proportion is lower, only 9.6%. This indicates that the rate of fragmentation of animal remains was higher at the flat settlement in comparison with the tell. In total, 15 species of mammal were identified – 5 domestic and 10 wild (Tables 1 and 2).

The remains of beaver and marten were found only in the flat settlement, whereas the remains and wolf and badger were found only in the tell settlement. The remains of all the other identified taxa were found in both parts of the settlement, although their relative proportions vary by location and occupation phase. At both settlements, the remains of domestic mammals are more numerous than those of wild mammals, although the relative proportion of wild mammals is slightly higher at the tell settlement (Fig. 15). Wild boar is the most frequently hunted species, followed by aurochs, red deer and roe deer. The other wild mammals present in the tell assemblage are hare, beaver, fox and marten (Table 2). The other wild mammals present in the flat settlement assemblage are hare, fox, wolf and badger (Table 1). The contribution of hunted mammalian species varies between 37.5% of mammal NISP in OP2 and 44% of mammal NISP in OP3 at the tell. The relative distributions of the remains of wild mammals varies between the flat settlement's occupation phases, and during OP 3, the remains of wild mammals comprise 55.4% of mammal NISP (Fig. 15). The high frequencies of wild mammals in all occupation phases in both the flat and the tell assemblage is taken to imply that the hunting was a significant activity of the Late Neolithic Gradište inhabitants for the procurement of meat and raw materials. However, animal herding was of greater importance. The existence of particular species in the assemblage, like the wolf, may indicate a rational approach to the control and management of the surrounding landscape by controlled hunting of a predatory species endangering domestic livestock of the settlement, but can

Common name	Latin name	OP 1		OP 2		OP 3		OP 4	
		NISP	% NISP	NISP	% NISP	NISP	% NISP	NISP	% NISP
Domestic cattle	*Bos taurus*	90	35.9	89	36.2	69	31.1	9	25.7
Wild cattle	*Bos primigenius*	11	4.4	15	6.1	35	15.8	-	-
Cattle (indet.)	*Bos* sp.	11	4.4	13	5.3	5	2.3	2	5.7
Domestic pig	*Sus domesticus*	25	10.0	24	9.8	17	7.7	5	14.3
Wild pig	*Sus scrofa*	42	16.7	21	8.5	28	12.6	1	2.9
Pig (indet.)	*Sus* sp.	8	3.2	9	3.7	3	1.4	3	8.6
Sheep	*Ovis aries*	-	-	2	0.8	-	-	1	2.9
Goat	*Capra hircus*	2	0.8	2	0.8	1	0.5	-	-
Sheep/goat	*Ovis/Capra*	32	12.7	26	10.6	8	3.6	6	17.1
Dog	*Canis familiaris*	4	1.6	7	2.8	5	2.3	1	2.9
Red deer	*Cervus elaphus*	12	4.8	18	7.3	33	14.9	5	14.3
Roe deer	*Capreolus capreolus*	9	3.6	17	6.9	17	7.7	2	5.7
Wolf	*Canis lupus*	-	-	2	0.8	-	-	-	-
Badger	*Meles meles*	1	0.4	-	-	-	-	-	-
Fox	*Vulpes vulpes*	2	0.8	-	-	-	-	-	-
Hare	*Lepus europaeus*	2	0.8	1	-	1	0.5	-	-
TOTAL		251	100	246	100	222	100	35	100

Table 1. Gradište. Trench 5, distribution of mammal remains at Gradište flat settlement as number of identified specimens (NISP) by occupation phase (OP).

Common name	Latin name	OP 2		OP 3		OP 4	
		NISP	% NISP	NISP	% NISP	NISP	% NISP
Domestic cattle	*Bos taurus*	40	49.4	352	38.6	284	39.5
Wild cattle	*Bos primigenius*	8	9.9	126	13.8	49	6.8
Cattle (indet.)	*Bos* sp.	1	1.2	43	4.7	32	4.5
Domestic pig	*Sus domesticus*	4	4.9	77	8.4	51	7.1
Wild pig	*Sus scrofa*	12	14.8	136	14.9	130	18.1
Pig (indet.)	*Sus* sp.	-	-	17	1.9	20	2.8
Sheep	*Ovis aries*	-	-	6	0.7	3	0.4
Goat	*Capra hircus*	1	1.2	4	0.4	4	0.6
Sheep/goat	*Ovis/Capra*	5	6.2	23	2.5	42	5.8
Dog	*Canis familiaris*	-	-	28	3.1	11	1.5
Red deer	*Cervus elaphus*	6	7.4	66	7.2	55	7.6
Roe deer	*Capreolus capreolus*	3	3.7	35	3.8	32	4.5
Fox	*Vulpes vulpes*	1	1.2	-	-	1	0.1
Beaver	*Castor fiber*	-	-	-	-	2	0.3
Marten	*Martes* sp.	-	-	-	-	1	0.1
Hare	*Lepus europaeus*	-	-	-	-	2	0.3
TOTAL		81	100	913	100	719	100

Table 2. Gradište. Trench 8, distribution of mammal remains at Gradište tell settlement as number of identified specimens (NISP) by occupation phase (OP).

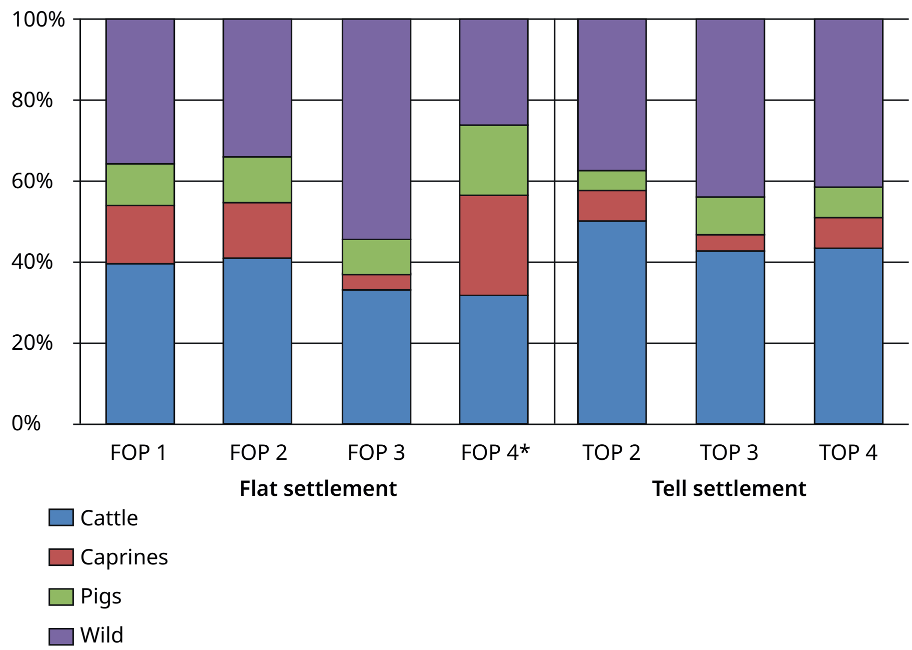

Figure 15. Gradište. Frequency (NISP) of wild and domestic mammalian taxa identified within the Late Neolithic settlement, by occupation phase (OP).

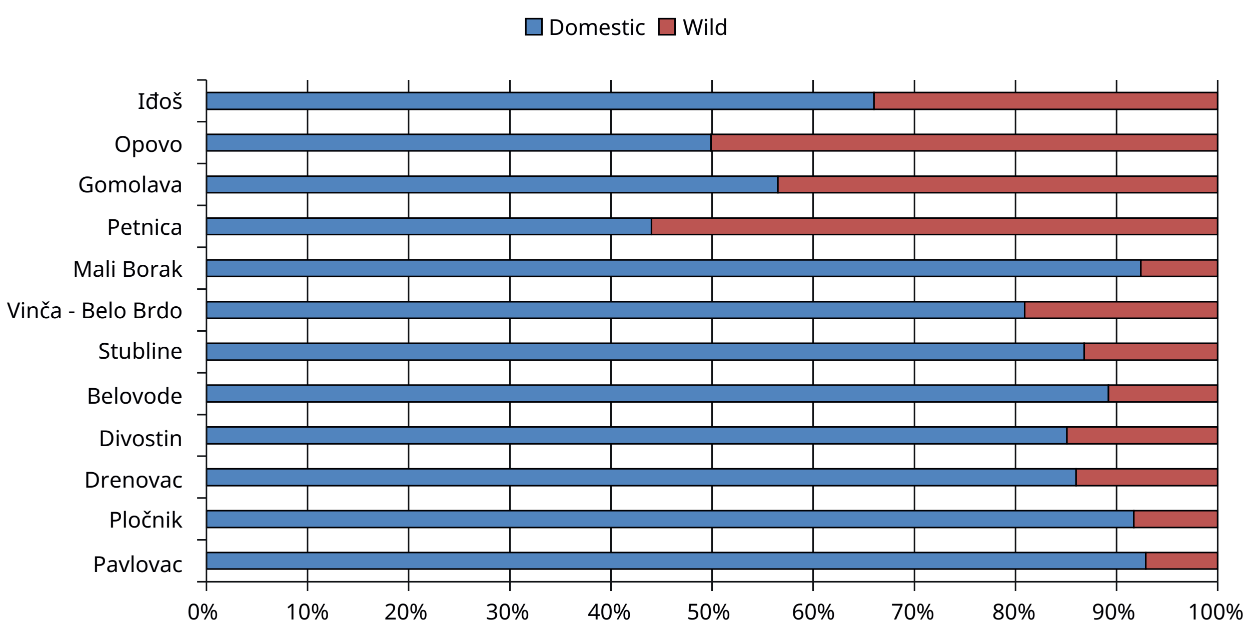

Figure 16. Ratio of domestic to wild mammal taxa on contemporary sites in the wider region around Gradište.

also be possible evidence of trade for exotic raw material or potential symbolic value material.

Domestic cattle are the most common taxon, and their remains comprise between 25% and 36% NISP of the flat settlement assemblages (Table 1) and between 38% and 50% NISP of the tell assemblages (Table 2). The difference in proportional representation between the two parts of the settlement is probably due to taphonomic reasons including the lower rate of bone fragmentation at the tell settlement, where cattle remains were better preserved and could be more often identified. Excluding the smallest faunal assemblage (from OP4, in the flat settlement) which contains a single example of caprine bone, the relative frequencies of caprines (sheep, goat and sheep or goat taken together) vary between 4% and 14%, and those of domestic pigs, between 5% and 11% (Fig. 15).

To check whether the distributions of the main domestic taxa (cattle, caprines and pigs) and wild mammals (taken together) vary significantly among the different occupation phases of the flat and tell settlements, thus implying a shift in herding and hunting strategies, we performed a chi-square test.[1] Although it showed a statistically significant relationship between the variables ($\chi 2$ (18)=81.978, p=0.001), the strength of the relationship is weak (Cramer's V=0.11), indicating that these differences are primarily the result of the sample sizes and that the strategies of herding and hunting did not change significantly over time in the Late Neolithic settlement of Gradište.

If we compare the proportion of wild and domestic mammals for the entire settlement (Fig. 16) against these quantities for other settlements of the period in the region, it clear that the ratio is more similar to that for the settlements of the Pannonian Plain than for those found in the southern, predominantly hilly areas of the Vinča core territory, where the population appears to have been highly dependent on domesticated mammals, predominantly cattle.

Conclusion

The preliminary results of the archaeological research on Gradište provide an insight into the development and transformations of a Late Neolithic society settled in the liminal area between two Late Neolithic cultures, on the southern boundary of the Pannonian Plain. The extensive geophysical survey of the site area indicates that the Early Neolithic settlements at the transitional phase between the Starčevo – Körös and Vinča – Tisza periods most likely consisted of scattered groups of dug-ins of smaller size situated on the edges of the Pleistocene terrace, above two regional streams. Data gathered during a systematic survey of the area (Trifunović 2012, 2016, 2020) show that Early Neolithic settlements outnumbering Late Neolithic settlements in a ratio of 1:4 (municipality of Čoka) to 1:10 (municipality of Kikinda), but the true ratios may be even higher, as the survey, although systematic, was not all-encompassing.

Looking at the settlement scale, the geophysical survey of Gradište shows indications for complex settlement structuring during the Late Neolithic, with rectangular wattle-and-daub objects of various sizes, orientations and complexities, depending on where in the settlement they were located (on the flat area or on the tell). The disposition of the settlement structures does not appear to conform to the layouts of other known settlements of the period, either in neighbouring areas or in the core areas of typical LBK or Vinča pottery, which would imply that its appearance and organisation are a product of the local population activities and decision making based on the availability and topographic features of the chosen settlement landscape.

Examining the intra-settlement disposition, we see that the clustering of structures in the flat settlement and the dense placement in rows of wattle-and-daub structures repeated through time on the tell may indicate the existence of land claims within the settlement, possible evidence of continued generational inhabitation by related individuals and families. The variation of structure sizes as well as structure complexity in the flat settlement may hint that these structures had a specialised function and a particular role in the settlement, but without further excavations, this assumption remains in the realm of possibilities.

The study of the material culture from the site, particularly the scientific analysis of pottery paste composition, suggests the existence not only of regional technological know-how superseding material culture boundaries, but also of

1 The result is considered to be statistically significant if the p-value is <0.05.

regional technological traditions transmitted through generations and visible in the processing of raw materials and choices of fabric depending on the vessel type. Furthermore, the inclusion of tempering material that is not available in the region may also be an indicator of vessel imports from regions to the north-east of the site, which would be a good confirmation that vessels could have been traded (in addition to scarce raw materials and resources as perhaps desired commodities).

Finally, if we look at the zooarchaeological evidence to illustrate the economy and aspects of the diet of the local community, we can see a clear indication of the prevalence of domestic over wild mammal taxa in the assemblage and a strong reliance on cattle, similar what is seen at other settlements of the period in the region. The existence of particular species in the assemblage, like the wolf, may indicate a rational approach to the control and management of the surrounding landscape by controlled hunting of a predatory species endangering domestic livestock of the settlement. Examples of wolf bones were found on other sites of the period in the surrounding region as well.

Combined, these strands of archaeological evidence, albeit partial and incomplete, illustrate continuous transformations in the liminal areas tucked away between major transit arteries of the Late Neolithic. They show dynamic societies, maybe small in population size but large in diverse activities and present in regional networks, taking on influences and ideas from the surrounding areas around them in what appears to have been a complex network of settlements and populations.

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References

Amicone, S., 2017. *Pottery technology at the dawn of the Metal Age: a view from Vinča culture.* Unpublished PhD dissertation, University College, London.

Amicone, S., Forte, V., Solard, B., Berthold, C., Memmesheimer, A., Mirković-Marić, N., 2021. Playing with fire: exploring ceramic pyrotechnology in the Late Neolithic Balkans through an archaeometric and experimental approach. *Journal of Archaeological Science: Reports*, 37, 1-18.

Amicone, S., Mathur, A.R., Pavitra, R.D., Mirković-Marić, N., Pantović, I., Kuzmanović-Cvetković, J., 2020. Beneath the surface: exploring variability in pottery paste recipes within Vinča culture. *Quaternary International*, 560-561, 86-101.

Amicone, S., Quinn, P., Mirković-Marić, N., Marić, M., Radivojević, M., eds., 2019. *Tracing pottery-making recipes in the prehistoric Balkans, 6th-4th millennia BC*. Oxford: Archaeopress.

Amicone, S., Radivojević, M., Quinn, P.S., Berthold, C., Rehren, T., 2020. Pyrotechnological connections? Re-investigating the link between pottery firing technology and the origins of metallurgy in the Vinča culture, Serbia. *Journal of Archaeological Science*, 118, 105-123.

Bánffy, E., Marton, T., Osztás, A., 2010. Early Neolithic settlement and burials at Alsónyék-Bátaszék. *In:* J. Kozłowski and P. Raczky, eds. *Neolithization of the Carpathian Basin: northernmost distribution of the Starčevo/Körös culture*. Kraków & Budapest: Polish Academy of Arts and Sciences & Institute of Archaeological Sciences of the Eötvös Loránd University, 37-52.

Bogdanović, M., 1988. Architectural and structural features at Divostin. *In:* A. McPherron and D. Srejović, eds. *Divostin and the Neolithic of central Serbia*. Pittsburgh: University of Pittsburgh Press, 35-91.

Borić, D., Hanks, B., Šljivar, D., Kočić, M., Bulatović, J., Griffiths, S., Doonan, R., Jacanović, D., 2018. Enclosing the Neolithic world: a Vinča culture enclosed and fortified settlement in the Balkans. *Current Anthropology*, 59 (3), 336-346.

Crnobrnja, A., 2012. Group identities in the central Balkan Late Neolithic. *Documenta Praehistorica*, XXXIX, 155-165.

Draşovean, F. and Schier, W., 2020. *Uivar 'Gomilă': a prehistoric tell settlement in the Romanian Banat*. Rahden: Verlag Marie Leidorf GmbH.

Girić, M., 1957. Neolitsko naselje kod Iđoša. Parcijalni izveštaj o iskopavanjima u 1954. godini. *Rad Vojvođanskih Muzeja*, 6, 219-230.

Gliozzo, E., 2020. Ceramic technology: how to reconstruct the firing process. *Archaeological and Anthropological Sciences*, 12, 1-35.

Grbić, M., 1950. Gradište kod Kikinde. *Starinar* (new series), 1, 113-118.

Grbić, M., 1951. Gradište kod Kikinde. Nastavak radova u 1948. godini. *Starinar* (new series), 2, 133-138.

Gyucha, A., Yerkes, R.W., Parkinson, W.A., Sarris, A., Papadopoulos, N., Duffy, P.R., Salisbury, R.B., 2015. Settlement nucleation in the Neolithic: a preliminary report of the Körös Regional Archaeological Project's investigations at Szeghalom-Kovácshalom and Vésztő-Mágor. *In:* S. Hansen, P. Raczky, A. Anders, A. Reingruber, eds. *Neolithic and Copper Age between the Carpathians and the Aegean Sea: chronologies and technologies from the 6th to 4th millennium BC: international workshop Budapest 2012*. Bonn: Dr. Rudolf Habelt GmbH, 129-142.

Hofmann, R., Medović, A., Furholt, M., Medović, I., Stanković Pešterac, T., Dreibrodt, S., Martini, S., Hofmann, A., 2020. Late Neolithic multicomponent sites of the Tisza region and the emergence of centripetal settlement layouts. *Praehistorische Zeitschrift*, 94 (2), 351-378.

Horváth, F., 1987. Hódmezővásárhely-Gorzsa: a settlement of the Tisza culture. *In:* P. Raczky, ed. *The Late Neolithic of the Tisza region: a survey of recent excavations and their findings*. Budapest & Szolnok: Directorate of Szolnok County Museums, 31-46.

Horváth, F., 1989. A survey on development of Neolithic settlement pattern and house types in the Tisza region. *In:* S. Bökönyi, ed. *Neolithic of southeastern Europe and its Near Eastern connections: International Conference 1987, Szolnok-Szeged*. Budapest: Institute of Archaeology of the Hungarian Academy of Sciences, 85-101.

Koutouvaki, E., Amicone, S., Kristew, A., Ştefan, C.E., Berthold, C., 2021. Shared traditions and shard conservatism: pottery making at the Chalcolithic site of Radovanu (Romania). *Archaeological and Anthropological Sciences*, 13 (11), 1-22.

Kreiter, A., Kalicz, N., Siklósi, Zs., Viktorik, O., 2017. Entangled traditions: Tisza and Lengyel ceramic technology in a Late Neolithic settlement in northern Hungary. *Journal of Archaeological Science: Reports*, 16, 589-603.

Lőrinczy, G., 2010. *Archaeolágiai Napló*. Szeged: Ferenc Móra Museum.

Makkay, J., Starnini, E., Biagi, P., Kaczanowska, M., Società per la preistoria e protostoria della regione Friuli-Venezia Giulia, 2007. *The excavations of the Early Neolithic sites of the Körös culture in the Körös Valley, Hungary*. Trieste: Società per la preistoria e protostoria della regione Friuli-Venezia Giulia.

Maniatis, Y. and Tite, M.S., 1981. Technological examination of Neolithic and Bronze Age pottery from central and southeast Europe and from the Near East. *Journal of Archaeological Science*, 8 (1), 59-76.

Marić, M., 2010. Arhitektura i idealna rekonstrukcija objekata od lepa. *Kolubara*, 5, 69-84.

Marić, M., 2013. Zaštitna arheološka istraživanja na lokalitetu Jaričište 1. *In:* V. Filipović, R. Arsić, D. Antonović, eds. *Rezultati novih arheoloških istraživaja u severozapadnoj Srbiji i susednim teritorijama*. Belgrade & Valjevo: Srpsko arheološko društvo & Zavod za zaštitu spomenika kulture Valjevo, 17-32.

Marić, M. and Mirković-Marić, N., 2020. The Tisza divide: the missing Late Neolithic transformation in the north Bačka region of Serbia. *Quaternary International*, 560-561, 78-85.

Marić, M., Mirković-Marić, N., Molloy, B., Jovanović, D., Mertl, P., 2016. New results of the archaeological excavations on the site of Gradište Iđoš. *Glasnik Srpskog Arheološkog Društva*, 32, 125-144.

Minichreiter, K., 1998. Ranoneolitički ukopi i pogrebni običaji u naseljima starčevačkog kulturnog kompleksa. *Prilozi Instituta za Arheologiju u Zagrebu*, 15-16, 5-20.

Mirković-Marić, N. and Amicone, S., 2019. Technological variances between Tisza and Vinča pottery. *In:* S. Amicone, P. Quinn Sean, M. Marić, N. Mirković-Marić, M. Radivojević, eds. *Tracing pottery-making recipes in the prehistoric Balkans 6th-4th millennia BC*. Oxford: Archaeopress, 96-112.

Molloy, B., Jovanović, D., Bruyère, C., Marić, M., Bulatović, J., Mertl, P., Horn, C., Milašinović, L., Mirković-Marić, N., 2020. A New Bronze Age mega-fort in southeastern Europe: recent archaeological investigations at Gradište Iđoš and their regional significance. *Journal of Field Archaeology*, 45 (4), 293-314.

Nikolić, D., 2020. Neolit i eneolit. *In:* S. Trifunović, ed. *Arheološka Topografija područja grada Kikinde*. Novi Sad & Petrovaradin: Muzej Vojvodine & Pokrajinski zavod za zaštitu spomenika kulture, 391-392.

O'Shea, J., 2011. A river runs through it: landscape and the evolution of Bronze Age networks in the Carpathian Basin. *Journal of World Prehistory*, 24, 161-174.

Paluch, T., 2012. *Maroslele – Pana: Egy középső neolitikus lelőhely a kultúrák határvidékén*. Szeged: Móra Ferenc Múzeum.

Parkinson, W.A., Gyucha, A., Karkanas, P., Papadopoulos, N., Tsartsidou, G., Sarris, A., Duffy, P.R., Yerkes, R.W., 2018. A landscape of tells: geophysics and microstratigraphy at two Neolithic tell sites on the Great Hungarian Plain. *Journal of Archaeological Science: Reports*, 19, 903-924.

Quinn, P.S., 2013. *Ceramic petrography: the interpretation of archaeological pottery & related artefacts in thin section*. Oxford: Archaeopress.

Raczky, P., 2012. Research on the settlements of the Körös culture in the Szolnok area: the excavations at Szajol-Selsőföld and Szolnok-Szanda. *In:* A. Anders and Zs. Siklósi, eds. *The first Neolithic sites in central/south-east European transect: the Körös culture in eastern Hungary*. Oxford: BAR, 85-96.

Raczky, P. and Anders, A., 2014. Szentpéterszeg-Kovadomb. Egy Késő Neolitikus Lelőhely Tér-képei. *In:* A. Anders, B. Csilla, A. Türk, eds. *Avarok Pusztái. Régészeti tanulmányok* Lőrinczy Gábor 60. *születésnapjára*. Budapest: Martin Opitz Kiadó – MTA BTK MŐT, 23-42.

Rassmann, K., Scholz, R., Mertl, P., Pendić, J., Jablanović, A., 2021. Pločnik: geomagnetic prospection data as a proxy for the reconstruction of house numbers, population size and the internal spatial structure. *In:* M. Radivojević, B.W. Roberts, M. Marić, J. Kuzmanović-Cvetković, T. Rehren, eds. *The rise of metallurgy in Eurasia: evolution, organisation and consumption of early metal in the Balkans*. Oxford: Archaeopress, 271-280.

Rassmann, K., Scholz, R., Mertl, P., Radloff, K., Pendić, J., Jablanović, A., 2021. Belovode: geomagnetic data as a proxy for the reconstruction of house numbers, population size and the internal spatial structure. *In:* M. Radivojević, B.W. Roberts, M. Marić, J. Kuzmanović-Cvetković, R. Thilo, eds. *The rise of metallurgy in Eurasia: evolution, organisation and consumption of early metal in the Balkans*. Oxford: Archaeopress, 94-108.

Santacreu, D.A., 2014. *Materiality, techniques and society in pottery production: the technological study of archaeological ceramics through paste analysis*. Warsaw: De Gruyter Open.

Schier, W., 2008. Uivar: a Late Neolithic-Early Eneolithic fortified tell site in western Romania. *In:* A.W.R. Whittle, D. Hoffmann, D. Bailey, eds. *Living well together? Settlement and materiality in the Neolithic of south-east and central Europe*. Oxford: Oxbow Books, 54-67.

Schier, W., 2014. Der spätneolithisch-kupferzeitliche Tell von Uivar (Rumänien). Prospektionen und Grabungen 1998-2009. *In:* W. Schier and M. Meyer, eds. *Vom Nil bis an die Elbe. Forschungen aus fünf Jahrzehnten am Institut für prähistorische Archäologie der Freien Universität Berlin*. Rahden: Verlag Marie Leidorf GmbH, 17-36.

Spataro, M., 2017. Innovation and regionalism in the Middle/Late Neolithic of south and south-eastern Europe (ca. 5,500-4,500 cal.BC): a ceramic perspective. *In:* L.B. Lanotte, ed. *Raw materials acquisition and processing in Early Neolithic pottery productions: proceedings of the Workshop of Namur (Belgium)*. Paris: Société préhistorique française, 61-80.

Spataro, M., 2018. Origins of specialization: the ceramic chaîne opératoire and technological take-off at Vinča-Belo Brdo Serbia. *Oxford Journal of Archaeology*, 37 (3), 247-265.

Stanković, S., 1992. Neolitsko naselje na lokalitetu Blagotin kod Trstenika. *Zbornik Narodnog Muzeja u Beogradu*, XIV, 77-87.

Trifunović, S., ed., 2012. *Arheološka topografija opštine Novi Kneževac*. Novi Sad & Petrovaradin: Muzej Vojvodine & Pokrajinski zavod za zaštitu spomenika kulture.

Trifunović, S., ed., 2016. *Arheološka topografija opštine* Čoka. Novi Sad & Petrovaradin: Muzej Vojvodine & Pokrajinski zavod za zaštitu spomenika kulture.

Trifunović, S., ed., 2020. *Arheološka topografija područja grada Kikinde*. Novi Sad & Petrovaradin: Muzej Vojvodine & Pokrajinski zavod za zaštitu spomenika kulture.

Tripković, B., 2013. *Domaćinstvo i zajednica. Kućne i naseobinske istorijer u kasnom neolitu Centralnog Balkana*. Belgrade: Filozofski fakultet, Univerzitet u Beogradu.

Vasić, M., 1936. *Preistoriska Vinča*. Belgrade: Državna štamparija Kraljevine Jugoslavije.

Plate 1

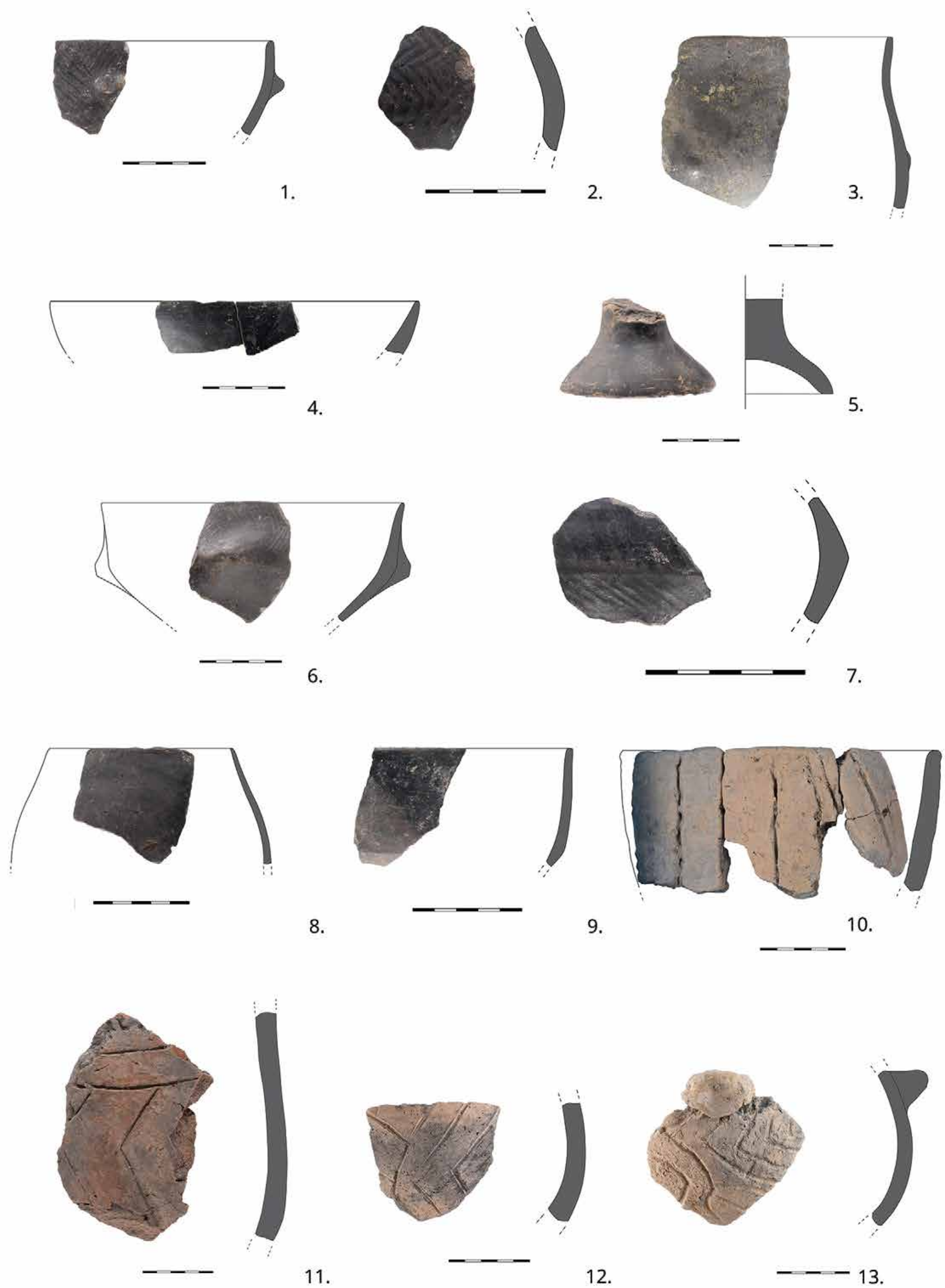

Plate 1. Gradište. Examples of typical Vinča-style pottery (1-9) and Tisza-style (10-13) pottery found during the 2015-2020 excavations.

Plate 2

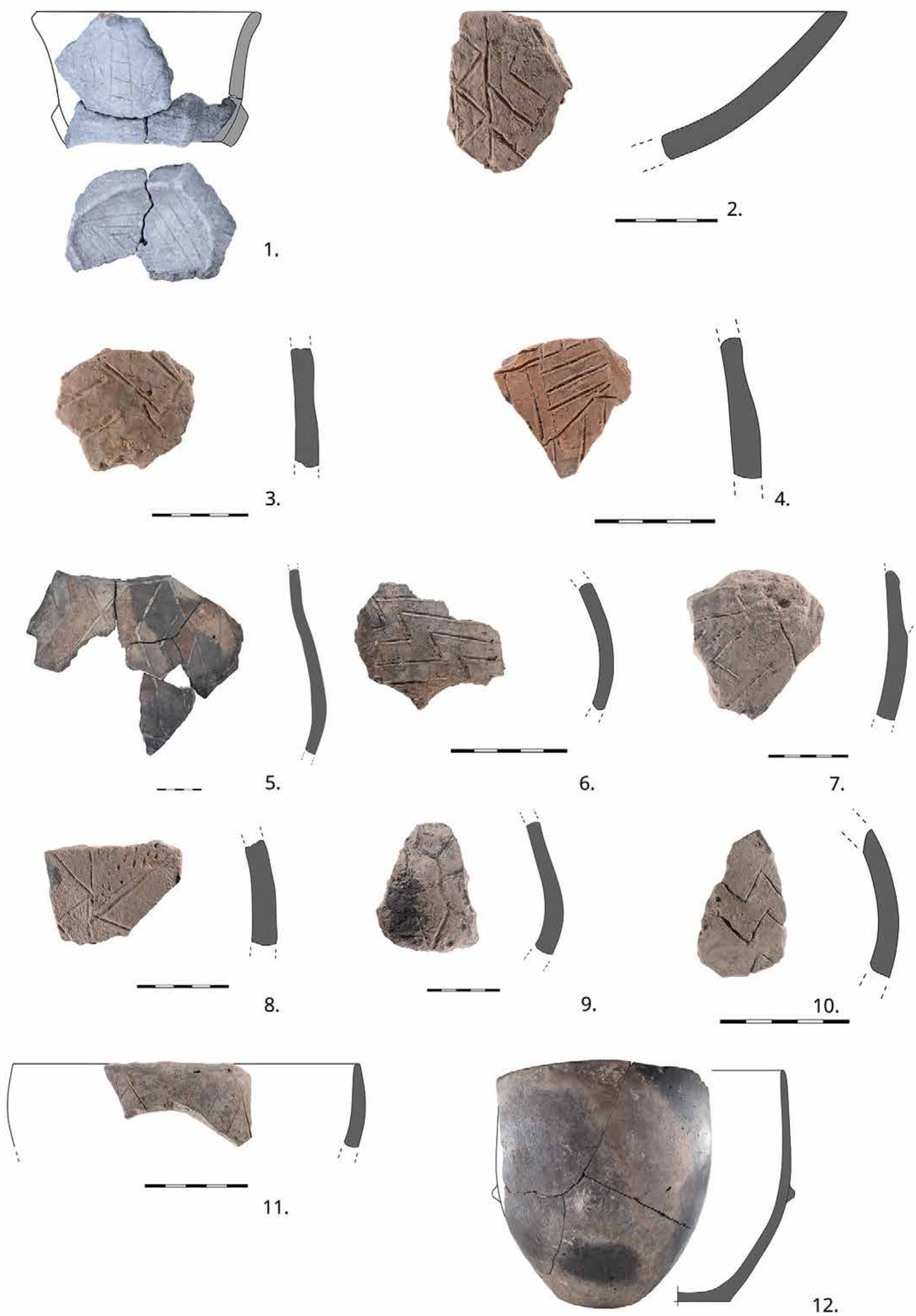

Plate 2. Gradište. Examples of typical Tisza-style (1-4) and Vinča – Tisza-style hybrid (5-12) pottery recovered during the 2015-2020 excavations (photos: Neda Mirković-Marić).

Circuits of reproduction:
The opportunities and power to change

Tamás Polányi

Abstract

In this paper, I articulate empirical data on contemporary political discourse about gun violence and death with theoretical considerations of the mechanisms and circumstances of indigenous social change. In so doing, I offer an agent-centred and human-scale approach to examine historical transformations through mortuary analysis. Understanding the role human agency and interaction play in the flows of history is a challenging task. Archaeology is well equipped to study history as sequences of transformative events linked together loosely by the thread of time, or as a continuous process of everyday life where time serves as a function of cultural persistence. However, concentrating on transformative events does not explain how those transformations occurred, why they took the shape they did, and ignores the underlying political discourses that necessitated and engendered change, as well as those that failed to do so. Similarly, focusing on continuous flows of mundane and habitual practice conceals the potentially fateful effect of human agency. To resolve such scalar discrepancy and to construct bottom-up narratives of how societies are organised and change over time, archaeologists often build on theory of structuration and derivative theories of practice. However, in these approaches, mechanisms behind scalar effects of the everyday are often assumed but not explored rigorously. Through reflecting on contemporary politics, I highlight a number of factors of political discourse critical for understanding their social and political consequences: (1) path dependence, the (2) situational authority and (3) knowledge of participating social actors, and (4) material conditions of communication. Building on such insights, I outline an approach centring on the politics of death and Anthony Giddens' largely overlooked 'combustion engine' of social change, the *circuit of reproduction*. I then turn towards the case of the Bronze Age community of Kajászó, Hungary (ca. 2000-1500 BC). Archaeological investigations at the cremation cemetery recovered materialities of political discourse considering change and persistence during the terminal phase of the community. Using evidence from Kajászó, I present implications of the outlined approach for mortuary archaeology foregrounding historical contingency, political discourse, and agency of participating social actors.

Keywords: *Bronze Age, Carpathian Basin, eventful archaeology, micro-archaeology, political discourse, power, agency, social change*

Introduction

Social change is often perceived as an earthquake shattering structured and institutionalised landscapes of human – material relations. It usually becomes recognised and perceived as an event (cf. Sewell 2005), a single and synchronous episode affecting multiple intersecting spheres of life and leading to the fundamental reconfiguration of social structures and institutions. Thus, in retrospect, social change becomes associated with detectable and definite adjustments, shifts, or disruptions in social, economic, and political practice and relations. In contrast, social change rarely becomes discernible and comprehensible as a process observing it directly in the moment.

This scalar discrepancy in perceptions of history and social change – elusive in the process but visceral and consequential in its effect – is acutely present in archaeology. Archaeology is well equipped to study history either as sequences of transformative events linked together loosely by the thread of time, or as a continuous process of everyday life where time serves as a function of cultural persistence. On a macro-scale, archaeology possesses the ability to paint grand syntheses of flows of history with a broad brush (Hodder 2000, 31). It helps to understand spans of time beyond human experience and comprehension by offering insight into sweeping reconfigurations of human – material relations and revealing varied articulations of enduring social, political and economic institutions (Earle 2003). In these narratives, historical transformations are regularly identified as events (Beck *et al.* 2007), which are understood better through their effect rather than their causality and content.

Such eventful interpretations of historical processes, however, are rooted in minute material residues of mundane acts of everyday life. Micro-scale of observations – inherent in archaeological research – allow a glimpse into fine-grained temporal sequences of histories and everyday experiences of past social actors. However, these distinct historiographies rarely become synchronised (Kristiansen 2008, 14), and in the process of constructing archaeological narratives of change, insufficient attention has been given to the role human agency and interactions played in long-term transformations (Hodder 2000, 22). To bridge the gap between the flows of history and human agency and interaction, most archaeological approaches employ statistical abstraction of material diversity and historical contingency obscuring such hallmark signatures of human agency. To provide more meaningful accounts of social change, archaeologists need to detect instances of political discourse about change and assess the ways in which human agency affects the course of history and gives shape of change (Johnson 2000, 211).

Accordingly, in this pursuit of mechanisms of social change, I view agency through its implications of power and politics (cf. Comaroff and Comaroff 1991; Giddens 1984; Johansen and Bauer 2011; Sewell 2005). Agency, from this perspective, refers to the capacity of knowledgeable social actors to engage in heterodoxic activities, to reinterpret and mobilise resources in innovative and creative ways, and in so doing, depart from cultural schemas – meanings, rules, and regulations informing social life – that initially structured such action. Exercising control over the production, circulation, and consumption of materialities of political discourse, social actors have the capacity to shape actions and perceptions of others, and by doing so, shape the structural conditions of their realities. Applying such restrictions on agency vis-à-vis human action, one can avoid diluting its analytical utility to examine the role social actors play in historical transformations. With such implications of human agency in mind, I turn to political discourse about gun control in contemporary US society as it offers important insights to conceptualise circuits of reproduction – a critical condition of social change. In the second half of the paper, I explore the archaeological applicability of this analytical framework.

Perceptions of change: the limitations of scale

When on June 26, 2015, the Supreme Court of the United States ruled marriage an undeniable right of all American citizens was an event (cf. Sewell 2005). It changed the lives and relations of many by allowing them to enter the social, legal, and financial contract of marriage. The event had a cascading effect reaching multiple segments and domains of society, which is well represented in the diverse political discourse in its aftermath. The event was highly publicised and materialised by people from all walks of life and in a wide variety of genres.

Too much emphasis on transformative events, however, can lead us to believe that history is just one damned thing after another. Such an eventful understanding of change considers history from a structural and systemic perspective. Social structure is understood as an arbitrary framework of meanings, rules, and regulations (Roseberry 1989, 8). It encapsulates human practice until it can no longer hold and explodes under the pressure of contradictions between the ideal social norms and the lived realities (Comaroff and Comaroff 1991, 26). Social change, therefore, seems to take a step-like form constituting seemingly stable and unchanging longer periods and periods of rapid structural transformations. In Clifford Geertz's words, '[t]he history of a great civilization can be depicted as a series of major events – wars, reigns, and revolutions – which, whether or not they shape it, at least mark major changes in its course. [...] [This] sort of historiography tends to present history as a series of bounded periods, more or less distinct units of time characterised by some special significance of their own' (Geertz 1980, 5).

Such structural and eventful approach to history often seems to be self-evident because most of social progress and interaction is doomed to remain invisible, hidden from the observer with no durable and recognisable rearrangement of human – material relations. The tireless decades-long effort and daily struggles of human rights activists and members of the LGBTQ+ community to upset status quo were dwarfed by the decision of the Supreme Court, and by the widely broadcast – materialised – announcement of the president. However, the invisibility and lack of immediate and discernible consequence of most political negotiation to upset existing status quo is neither predetermined, nor self-evident. This is tragically apparent in the distinct sociopolitical consequences of mass shootings at Sandy Hook Elementary School in Newton, Connecticut (Sandy Hook), Harvest Festival in Las Vegas, NV (Las Vegas), First Baptist Church in Sutherland Springs, TX (First Baptist), and Marjorie Stoneman Douglas High School in Parkland, FL (Stoneman Douglas) (Table 1). These occurrences reveal important factors about change and stasis and about the ways in which they affected political discourse over gun control.

Date	Location	Death/Injury (Statista 2022)	Rank in mortality
01/10/2017	Route 91 Harvest festival, Las Vegas, NE	58/546	1
14/12/2012	Sandy Hook Elementary School, Newtown, CT	27/2	4
05/11/2017	First Baptist Church, Sutherland Springs, TX	26/20	5
14/02/2018	Marjory Stoneman Douglas High School, Parkland, FL	17/14	9

Table 1. List of mass shootings mentioned in the paper.

Measuring change: the efficacy of human agency

Due to the almost universal spread of social networks and internet, big data and data science provide extraordinary new sources of information and analytical methods for social scientists (Brady 2019). For example, aggregate search queries – supported by a number of online platforms (*e.g.* Google Trends) – provide data to gauge not only what the public cares about but to measure the intensity and endurance of civic engagement. Online search is an active form of information acquisition, and it presumes the searcher (actor) has some degree of prior knowledge and motivation for interpersonal engagement (Granka 2013, 272). Studies of internet use vis-à-vis politics demonstrated positive association between high levels of political self-efficacy and online surveillance of political issues (*e.g.* Kaye and Johnson 2002). Individuals who felt more like they could effect change in government were more likely to keep up with and seek out political information online (Robertson 2018, 55). Furthermore, it has been demonstrated that trends in online search queries centring on certain political issues reliably track their prominence in public consciousness (Granka 2013). In sum, online information seeking behaviour can be considered a reliable proxy for political discourse. Through diachronic and quantitative assessment of online search traffic one can measure the durability and intensity of public discourse over politicised issues.

Undoubtedly, there are numerous characteristics of the above tragic occurrences of death that set them apart and to expose them would require a nuanced sociopolitical analysis not feasible within the confines of this paper. However, focusing on the extent to which these tragedies affected political discourse offers valuable insights into necessary material conditions of effectuating social change. Even a brief comparison of the intensity and endurance of political engagement these mass shootings triggered seems to defy logic. The discrepancy is further highlighted if we consider two related occurrences: President Barack Obama's speech on gun control on January 16, 2013 (Obama speech) and the *March for Our Lives* protest (MFOL) on March 24, 2018, organised by surviving high school students of the Stoneman Douglas shooting.

Figure 1 illustrates changing interest in gun control in the US based on metadata of Google Search queries for 'gun control' (Google Trends 2018) betwixt Sandy Hook and Stoneman Douglas. Values along the Y-axis represent search interest relative to the highest point on the chart for the given time period. A value of 100 is the peak popularity for the term. A value of 50 means that the term is half as popular. For better visualisation, data between April 1, 2013, and September 30, 2017, have been omitted from the graph.

As seen on Figure 1, there were three extreme peaks in the intensity of political discourse regarding gun control in the last decade; and the direct aftermath of the tragedy at Sandy Hook is not one of them, nor is the fifth-deadliest mass shooting in US history at the First Baptists Church on November 5, 2017. These occasions include the Obama speech and the immediate aftermath of the Las Vegas and the Stoneman Douglas shootings. Difference in the endurance of the effect of these tragedies on political discourse is also striking. Public engagement dwindled in a week or so in all cases, except for the aftermath of Stoneman Douglas. The level of media exposure of surviving Stoneman Douglas high school students, which was further amplified by their situational authority as surviving witnesses, generated unprecedented durability in political discourse related to gun control. In fact, MFOL protest – organised by survivors of Stoneman Douglas – activated a level of political engagement and awareness that surpassed such effect in the aftermath of the violent death of 20 young children and six adult caretakers at Sandy Hook.

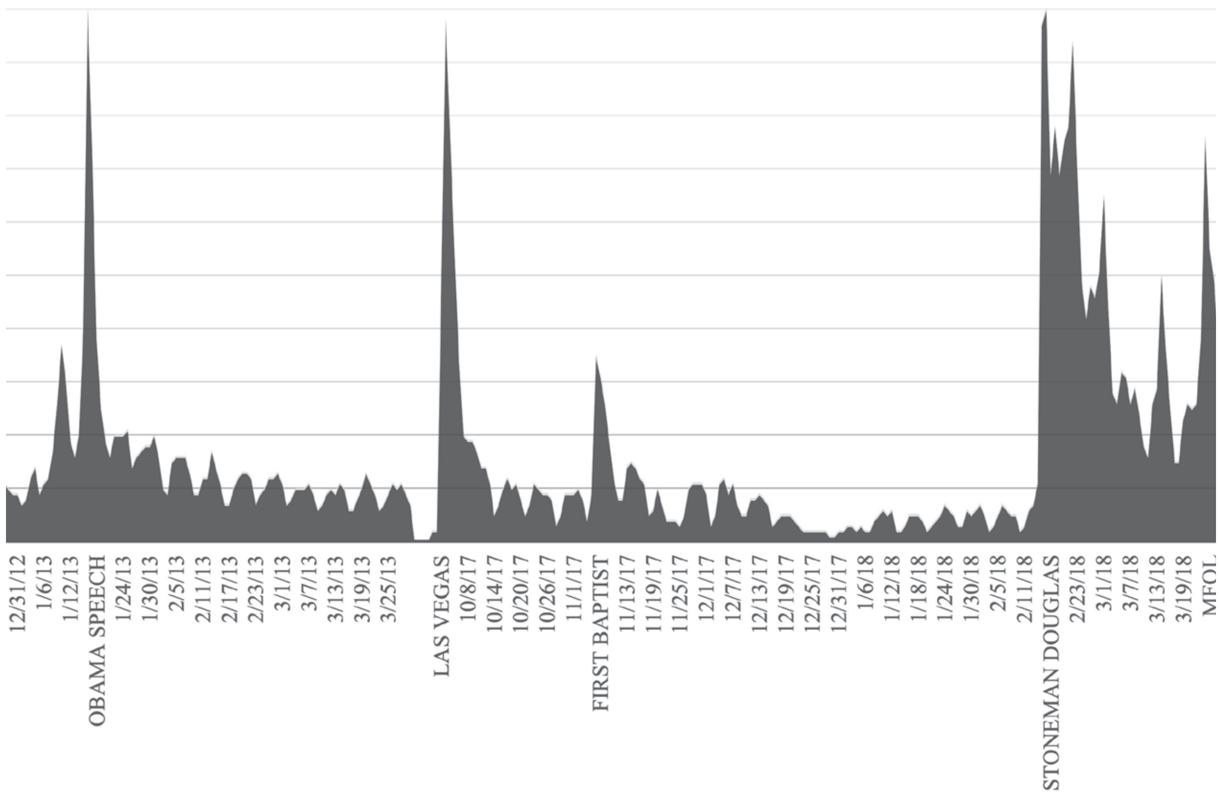

Figure 1. Level of interest in gun control based on number of Google Search queries in the US (Google Trends 2018).

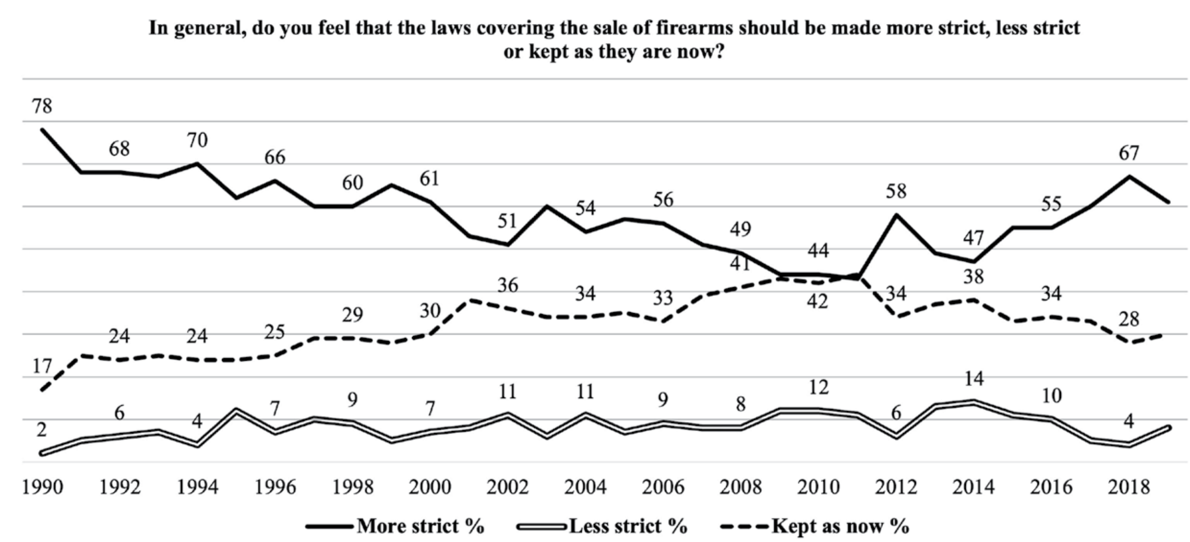

Figure 2. Polling data from the last three decades regarding the adequacy of gun regulations in the US (Gallup 2022).

Another important aspect of political discourse on gun control is how it contributes to social change regarding the importance of firearms in US identities and politics. Polling data on gun control laws, reaching back to the early 1990s, provide surprising results (Fig. 2). Despite the appearance and pervasiveness of internet-based media and almost unlimited access to information, a significant increase in the deadliness[1] and frequency of mass shootings, stricter gun control laws were significantly more popular three decades ago than they are now, and comprehensive federal gun control laws to curtail this epidemic are nowhere in sight.

Although these examples of political discourse and social change – or the lack of it – seem to be far removed from historical transformations of Bronze Age communities, they raise important questions regarding the mechanisms of change and persistence. What is common among circumstances that prompt extreme intensity in political discourse? Why is there a significant discrepancy between the amplitude and endurance of political discourse in the aftermath of such tragic events? What made the survivors of Stoneman Douglas more consequential agents of change than the President of the United States?

Envisioning change: theories of structuration

Historical analyses necessitate unravelling of political discourse and relations between actors and durable structures to explore ways histories acquire shape and texture through continuous flows of action (Wolf 1982, 23). Therefore, historical research revolves around the dichotomies of structure and agency, the habitual and the political, or enduring institutions and quotidian practical politics, and strives to explore the role of social actors in change and persistence. Most anthropological frameworks attempting to transcend these dichotomies can be traced back to the theory of structuration (Giddens 1984) and the concept of habitus (Bourdieu 1977). The theory of structuration, and derivative theories of practice (Ortner 1984), emphasise ongoing practice of knowledgeable social actors, through which they continuously produce and reproduce structures, which in turn both enable and restrict social action. Despite its wide applicability, the theory of structuration has been criticised for being too abstract, for ignoring and obfuscating material processes, and for its inability to elucidate indigenous change (*e.g.* Beck *et al.* 2007; Preucel 2006). Furthermore, the emphasis on mundane acts of everyday life impedes our understanding of the efficacy of individual decisions in advancing, negotiating, and contesting social change (Brumfiel 2011). As Sahlins (2002, 23) warned, we must avoid translating the apparently trivial into fatefully political by giving special attention to the articulation of the habitual and the political.

To better understand the role and weight of human agency in engendering social change, anthropological research turned towards establishing the socio-historical, or spatio-temporal contexts of political discourse,[2] instances of practical realisation of cultural categories in specific historical contexts (Sahlins 1985). Such encounters of contradictory consciousness (Gramsci *et al.* 1971, 333) – the recognition of divergence between what the world is and what it should be – manifest in condensed political discourse when the quotidian takes on an explicit political significance, and simultaneously becomes marked (cf. Keane 2010), materialised, and detectable against the backdrop of habitual processes of everyday life. Political discourse, in

1 Based on publicly available data, 11 of the 25 deadliest mass shootings on record since 1966 in the USA occurred within the last 5 years (Statista 2022).

2 This turn towards the political can be identified in political ecology (Johansen and Bauer 2011), ritual economy (Wells and Davis-Salazar 2007; Wells and McAnany 2008), historical processualist (Beck *et al.* 2007; Sahlins 1985; Sewell 2005) and pragmatic anthropological (Preucel 2006) approaches.

this sense, manifest in cooperative acts or resistance to structures of power by a variety of social actors as willing and active, intentional, and conscious participants in diverse interdependent relationships and institutions.

Aside from myriad historical contingencies of the above-mentioned mass shootings, they present an important parallel that helps explain their recurring effect on ongoing political discourse about gun control. They were instances of contradictory consciousness, moments of reckoning with the inefficiencies of social institutions, rules, and regulations to effectively protect human lives. Such realisation is especially striking upon the death of children. As expected, against the backdrop of a constant but low-level political engagement about gun control, a significant increase in the intensity of political discourse could be measured in the immediate aftermath of each occurrence (Fig. 1). Scrutiny of the data, however, reveals important variation, namely the oversized intensity and – in the case of the latter – endurance of political engagement engendered by the Obama speech and MFOL protests. These examples highlight four critical factors of political discourse: (1) path dependence, the (2) situational authority of (3) knowledgeable social actors, and the (4) material conditions of political discourse.

Mechanisms of change: socio-historical conditions of political discourse

Meanwhile most everyday occurrences can be shown to have major and unpredictable consequences at a certain scale, every act is part of a sequence of actions and the scale and directionality of its effects are profoundly dependent upon its place within that sequence, a condition referred to as path dependence in historical sociology (cf. Mahoney 2000; Sewell 2005:100). Accordingly, the effects of a given occurrence may be magnified, compounded, and broadcast, or alternatively, nullified and deflected by previous, subsequent, or simultaneous happenings. Both the Obama speech and the initiation of the MFOL protests took place a month after mass shooting at Sandy Hook and Stoneman Douglas, respectively. Although, these acts of political engagement were not themselves instances of contradictory consciousness, their political effect was a function of their temporal proximity to one. To better understand the social consequences of political action and the efficacy of human agency, one must consider their social temporalities at the scale where human action takes place and is perceived.

Temporality of political discourse, however, does not provide an adequate explanation for the increased endurance of political discourse triggered by Stoneman Douglas and the related MFOL protests. Recent approaches to politics and power build on the understanding that – due to the dispersion and fluidity of power in societies – the process of political control is never complete, and, inevitably, enactment of power creates frictions (Comaroff and Comaroff 1991, 17). Within such amorphous manifestations of power, knowledgeable social actors with thorough and indisputable knowledge of occurrences of contradictory consciousness are able to gain situational authority, a contingent and context-specific power to set the agenda for public discourse over politicised issues. Political acts of surviving witnesses of Stoneman Douglas manifested in public engagement regarding gun control with previously unprecedented durability (Fig. 1). Despite their young age and political inexperience, their demands for stricter regulation resonated with larger percentage of the American population than similar demands made by arguably one of the most powerful individuals in the world. Recognising situational authority is critical to detect instances, when political actors navigate, negotiate, consent, or contest the taken-for-granted, the *status quo*.

Mechanisms of change: material conditions of political discourse

What set survivors of Stoneman Douglas apart from survivors of Sandy Hook, is that they acted as knowledgeable social actors proficient in manipulating readily available and hard-to-control digital media of communication, thus capable of direct engagement in political discourse (Bromwich 2018; Kosoff 2018; Ohlheiser and Epstein 2018). As a Washington Post columnist put it at the time, '[t]he Parkland kids are rising to the occasion because they have to and because they have the skills. The Columbine High School shooting took place before social media, and the Sandy Hook survivors were too young' (Fowler 2018). The consequences and the efficacy of human agency are inextricably linked to material conditions which they invoke. An integrated approach to material culture triangulating materiality, materialism, and materialisation offers useful vocabulary to clarify (Earle 2013). *Materiality* is the quality of being physical, durable, and manipulable. Materiality is critical to understand the ways in which intersubjective exchanges become social – real – and simultaneously imbue objects and material contexts with meaning and value. *Materialism* argues that physical conditions of resources, technology, and cultural objects determine and are determined by social and political relations of power. Access to materiality enables or limits social action and determines the effect of human agency. Finally, *materialisation* is the process though which social actors construct and manage meaning and structure social relationships. It refers to the transformation of worldviews, values, stories, identities, and the like into physical realities, comprehensible media of communication, and enduring mnemonic devices that can preserve, broadcast, and carry social meaning.

Approaches to politics and power often acknowledge the ways in which certain forms of materiality are privileged as dominant media of communication accessible to and controlled by the elite, while others are neglected (Miller 2005, 19). Limiting or allowing people's access to media to materialise ongoing negotiations of cultural norms and social identities is operational in politics of power (Earle 2004, 112). In his study of the Mankon chiefdom in the Grassfields region of Cameroon, Michael Rowlands (2005, 80) draws attention to hierarchical materiality – a condition of unequal access to materialities for self-actualisation – and points out that one's ability to become fully material is not solely a factor of access to resources but contingent upon active participation in practical activity, which, in turn, can be limited or eliminated altogether. Such control, however, can be overcome by creative consumption and manipulation of hard-to-control materialities of the everyday. For example, Mark Hauser (2008) showed how production, distribution, and consumption of locally produced utilitarian clay pots generated the necessary material condition of communication among the enslaved that ultimately led to the organisation of the 1831 emancipation war in Jamaica. Therefore, to move beyond detection of obvious markers of political discourse, the assessment of quotidian practices and habitual relations is necessary to identify alternative means of political discourse and to contextualise their meaning.

With no enduring and privileged material residues, minor ruptures of social structure are limited in their spatial and temporal consequence, and thus remain hardly recognised with no fateful social effect (Sewell 2005, 7). To put it in other words, most political interactions remain micro-scale, culturally non-existent and therefore historically inconsequential. Consequently, history often appears as a sequence of major events, often referred to as 'turning points' or 'watersheds' associated with particular dates and assigned to prominent actors. The above examples, however, highlight that the alignment of certain conditions not only enhance the efficacy of human agency engendering indigenous change, but can offer a valuable insight into the ways histories acquire shape and texture. Such 'engines of change' are

defined here as sequences of historically situated and interrelated instances of condensed political discourse – occurrences of contradictory consciousness – where knowledgeable social actors acquire situational authority and engage in the materialisation of values and beliefs through creative, divergent, and heterodoxic processes of production and consumption.

Engines of change: funerals as circuits of reproduction

There is an underdeveloped and overlooked element of Giddens' theory of structuration, which encapsulates the above outlined conditions of indigenous change. Giddens describes particular moments of potential structural transformation – circuits of reproduction – that become 'implicated in the 'stretching' of institutions across space and time. [...] They serve indeed to indicate some of the main forms of change involved in the transition from one type of social totality to another' (Giddens 1984, 190-191). Giddens also notes that this particular situation involves the 'clustering of institutionalized practices across space and time' (ibid., 190), and highlights that 'reflexive monitoring of action in situations of copresence as the main anchoring feature of social integration, but both the conditions and the outcomes of situated interaction stretch far beyond those situations as such' (ibid., 191). Disguised by Giddens's impenetrable prose, circuits of reproduction[3] define situations of high-density public and political interaction articulating various social and economic institutions and accompanied by reflexive self-awareness of knowledgeable actors. It is in these encounters, Giddens states, where effects of human – material interaction can reach beyond their immediate context and can engender structural change.

Mechanisms envisioned in circuits of reproduction can be archaeologically detected within the mortuary domain. There are, however, some theoretical limitations embedded in mortuary archaeology that hinder envisioning agency, creativity, and political discourse in the mortuary domain ultimately rendering it apolitical and ahistorical. Despite well-established approaches to mortuary practice promoting the perspectives and the agency of mourners (Pearson 1999), mortuary archaeology seems to be trapped in the 'fallacy of symbolism' (Pels 2010, 231). Funerary practice is often conceived as a nomothetic institution, where liturgy is considered a static representation of social identities centring on wealth and status of the deceased or determined by biological facts, such as age at death or sex (cf. Polányi 2022; Schug 2020).

Ritual economy – an analytical strategy explaining how in middle-range societies worldview, economy, power, and agency interlink in society and social change (Wells and Davis-Salazar 2007; Wells and McAnany 2008) – offers a theoretical framework that helps substantiate funerals as circuits of reproduction. Ritual economy approach privileges both ritual acts and economic processes of production, allocation, and consumption implicated within them. By emphasising the *economy of ritual*, it expands on the understanding of ritual practice in two important ways. First, it conceptualises ritual participants as intentional and conscious actors engaging in diverse, interdependent social relationships and institutions. Second, it defines the ritual domain as an articulation of varied economic institutions where ritual practitioners engage in materialisation of values and beliefs for managing

3 Since Aristotle's Πολιτικά, circuits of reproduction have been recognized as powerful engines of change. The philosophy of *trias politica*, the separation of three branches of government – legislative, judiciary, executive – is meant to circumvent the development of circuits of reproduction. In the absence of *trias politica*, societies are prone to develop authoritative regimes, which can initiate and enact structural changes with a stroke of a pen.

meaning and shaping interpretation (Wells 2006, 284). Simultaneously, by stressing the *ritual of economy*, it recognises the sociopolitical weight of public ritualisation of otherwise quotidian social and economic acts. Enactment of ritual temporarily diverts public attention and resources constructing an opportunity for social actors to normalise, resist or negate relations of power; legitimise actions; and construct narratives about how the world operates (Polányi 2022, 2). Thus, quotidian practices and materialities of everyday life become implicated in ritual practice by taking on indexical forms (cf. Preucel 2006), and – through processes of materialisation – embody and substantiate public and durable propositions. These materialities become tangible proof of moral order, which, in turn, inform sociopolitical and economic relations and everyday life, and become habitual, unquestioned, uncontested.

Finally, the anthropological concept of liminality (Turner 1969; van Gennep 1909) completes the conceptualisation of mortuary practice as a moment of contradictory consciousness. Communities can be conceptualised as actively constructed contingent webs of social, political, and economic relations (Canuto and Yaeger 2000). Death disarticulates such webs of relations by breaking up alliances and reciprocal relations, patterns of interaction, craft, and consumption. It exposes contradictions between the social world as habitually constructed and as practically experienced. Liminality induced by death provides room for creativity, improvisations, and alternative social arrangements. Attempts to rearticulate relations take form in mortuary ritual. Thus, funerals are emotionally charged moments of concentrated attention that invoke the process of reconfiguring a community. This process involves political, discursive, and conscious action for materialising propositions, which then circulate socially and endure historically. In the predictable and reliable repetition of death, funerals establish easily recognisable contexts within which ritual practitioners can detect opportunities to act outside the conventions of daily life. Consequently, examining sequences of funerals can inform us about political processes as ritual participants normalise, resist or negate newly formulated relations; legitimise actions; and construct new narratives about how the world operates.

Archaeology of funerals as circuits of reproduction

Conceptualising funerals as circuits of reproduction has important implications for mortuary archaeology. First, conceptualising mortuary practice as the articulation of habitual and political implies that materialities of funerary practice are derivatives of quotidian human – material relations that become (re)appropriated, manipulated, and deployed within the mortuary domain. Funerals – historically contingent moments of political discourse – should be examined contextually against detailed historical trajectories implicated within the framework of economic and social practices and material conditions of everyday life. Contextualization of the mortuary domain assists the identification of varied and *changing* repertoires of material practice that become operational in the politics of death. The ways ritual participants engage with such means of differentiation, culturally embedded or novel, local or external, utilitarian or prestige, set against the quotidian, may present active and creative acts of negotiation engendering change within the mortuary domain.

Second, prioritising agency in mortuary analysis implicates funerals as an active domain where ritual participants engage in discursive processes of materialisation. Such an analytic strategy invokes the interpretation of material residues of mortuary practice as signs that are part of larger sets of indexical

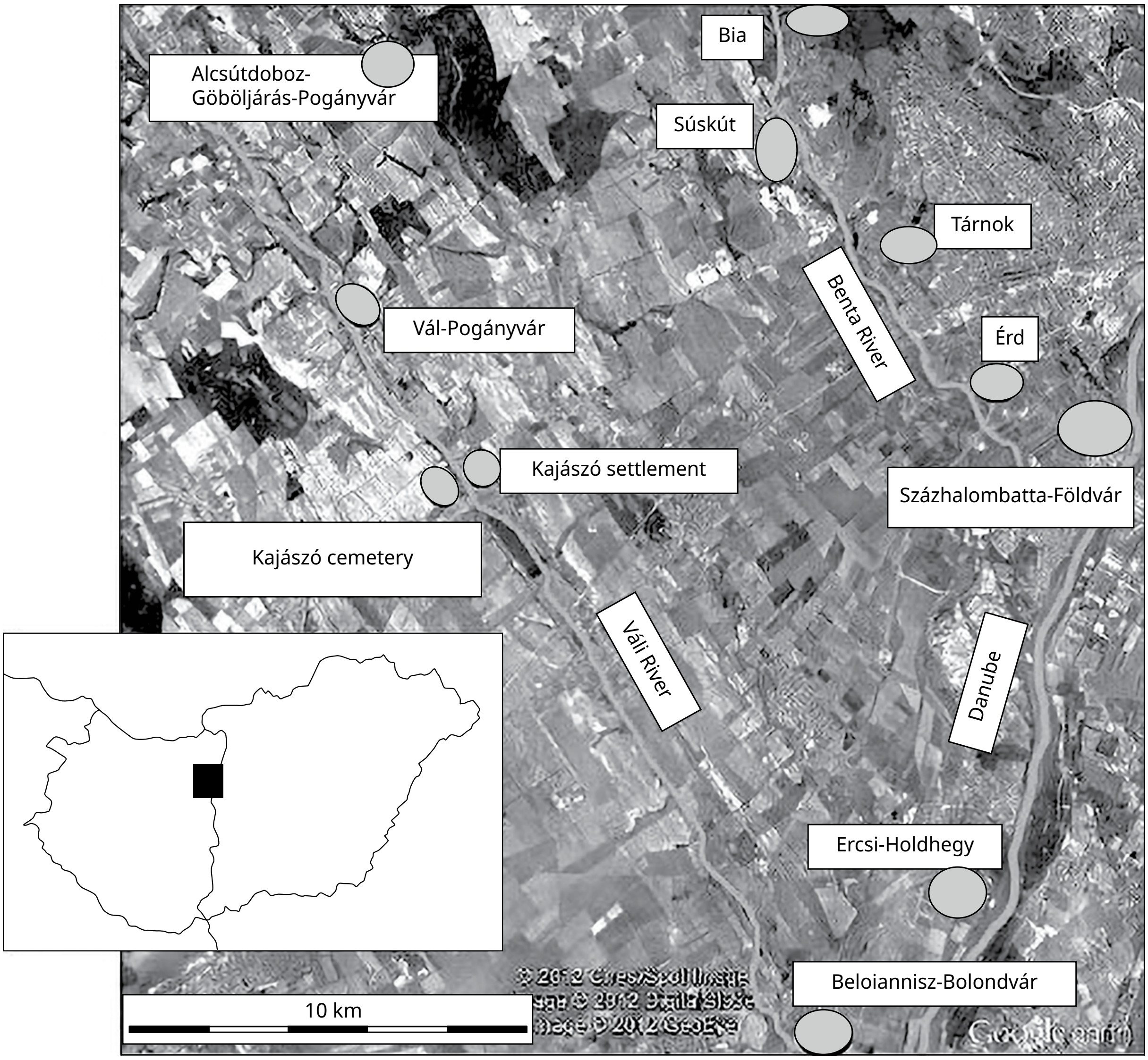

Figure 3. Kajászó cemetery and Bronze Age settlements of along the Váli Valley and the neighbouring Benta Valley, central Hungary. Background image from Google Earth.

practice, which proposes that no form of communication has meaning in and of itself, but meanings are formulated cognitively and realised culturally through human – material interaction. It is an important departure from pursuing trans-historical – and often trans-cultural – laws to define the relationship of signifier (material residue) and signified (social, economic, or biological categories). To draw on Richard Parmentier's (1987) categorisation of signs, funerary assemblages are constituted of *signs in history*, value-laden objects implicated in social strategies that focus attention on specific historical processes and manifest historical intentionality, as opposed to being *signs of history*, retrospective and symbolic reflections of the past.

Third, conceptualising funerals as historically contingent and discursive moments of contradictory consciousness has transformative implications for cemetery analyses. To support emic understanding and interpretation of material residues of political discourse and agency, burial assemblages should be studied sequentially; repertoires of material practice deployed at funerals must be evaluated relationally and in their spatio-temporal contexts to avoid the assignment of absolute values and trans-historical meanings to materialities of death.

Figure 4. Location of the Bronze Age settlement and cemetery of Kajászó.

Bronze Age community of Kajászó

In the rest of the paper, I present a case study to illustrate the interpretative consequences of the above delineated analytical approach to mortuary practice and social change. The Bronze Age community of Kajászó occupied prime agricultural lands suited for cereal crops and herding and was incorporated in a Bronze Age polity along the Váli, a tributary of the Danube flowing north-west to south-east (Fig. 3). Like the neighbouring Benta Valley, the that of the Váli showed clear signs of political centralisation at the turn of the EBA to Middle Bronze Age (MBA) (Earle and Kristiansen 2010; Szeverényi and Kulcsár 2012); a process linked to the organisation of Danubian trade in bronze items, raw materials, and secondary animal products during the Bronze Age (Kiss 2011; Earle 2002; Sherratt 1993).

The fortified settlement of the community, Kajászó-Várdomb (Kovács 1969; Nováki 2004) is located 16 km removed from the Danube and situated on an elevated plateau at the eastern bank of the Váli Valley (Fig. 4). Limited surveys and unpublished probing at the settlement indicate a major Middle Bronze Age occupation, encompassing at least 1.7 ha (Szeverényi and Kulcsár 2012).

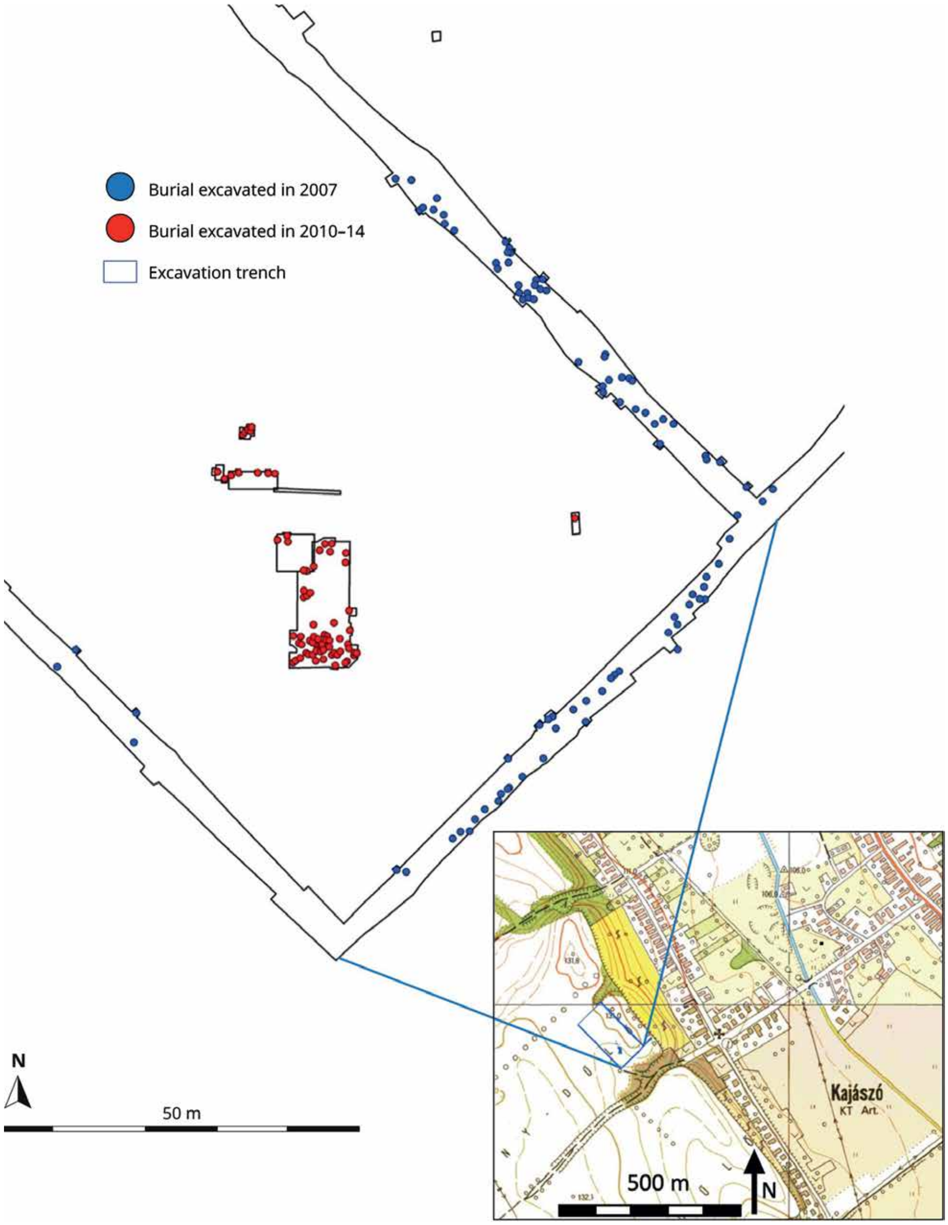

Figure 5. Distribution of burials unearthed during the 2007 and 2010-2014 excavation campaigns. Blue dot=burial excavated in 2007; red dot=burial excavated in 2010-2014; black polyline=edge of the excavation trench.

Date	Investigation / Institution	# of excavated burials	Reference
2007	Salvage excavation along utility pipelines / Szent István Király Museum	90	Kovács 2008
2010	Shovel testing, geophysical survey, test excavation of 37 m² / Northwestern University	11	Polányi 2010, 2018
2013-2014	Geophysical survey, shovel testing, test excavation of 196 m² / Northwestern University	62	Polányi 2014, 2018
2020-	Intermittent salvage excavations / Szent István Király Museum	60+	Kovács pers. comm. 2021

Table 2. Overview of archaeological investigations at the Bronze Age cemetery of Kajászó.

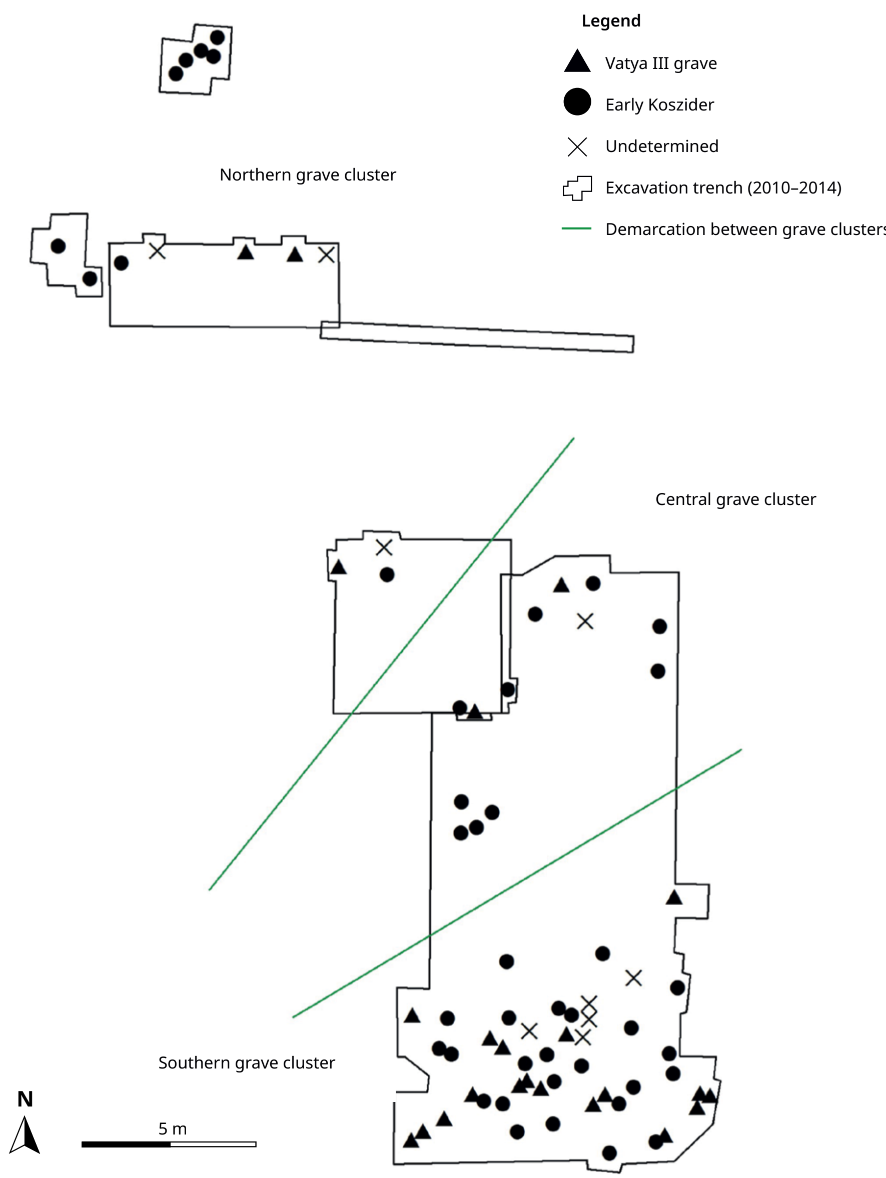

Figure 6. Typochronological classification of graves uncovered during the 2010 and 2013-2014 excavations.

Clearly visible from the settlement, the cemetery of the community is located on an elevated plateau across the valley, approximately 0.9 km to the west-south-west, encompassing 1.3 ha. At the cemetery, extensive rescue excavations began in 2007 (Kovács 2008). Since then, various excavation campaigns unearthed over 220 burials (Fig. 5, Table 2). Based on the typochronological data acquired during the rescue excavations, the cemetery and the contemporaneous settlement were likely in use by the Kajászó community during the end of the Early Bronze Age (EBA III) and throughout the MBA between approximately 2000-1500 BC (Kiss *et al.* 2019; Laabs 2013; Vicze 2011).

As part of a research project (Polányi 2018), investigations between 2010 and 2014 were designed to recover complexities, idiosyncrasies, and constituting processes of mortuary practice to recover instances of political discourse, human agency, and creativity. During two field seasons, 76 cremation burials were excavated, which – except for one – constituted three grave clusters (Fig. 6). Although samples were collected, lacking sufficient funds, no radiocarbon dating has been completed. Based on typochronological assessment of recovered material assemblages, the burials were dated to the final period of the cemetery at the turn of Vatya III – Early

Non-local, easy-to-control means of differentiation	Bronze objects
	Imported vessels
	Regional pottery
	Local imitation of non-local pottery
Hard-to-control means of differentiation derivative of quotidian human – material relations	Local pottery
	Differential treatment of the body
	Differential investment (quality and quantity)
	Spatial differentiation by pyre
	Spatial differentiation by grave

Table 3. Repertoire of political discourse.

Koszider (Laabs 2013), or MBA III – MBA IV (Vicze 2011; for broader chronological synchronisation, see Polányi 2022, Fig.3).

As noted previously, establishing links between quotidian practices and material conditions of everyday life and mortuary behaviour helps to assess available and changing means of differentiation – culturally embedded or novel, local or external, utilitarian or prestige – and to detect the ways in which ritual participants manipulated such materialities in the mortuary domain (Table 3). Although previous excavations at Kajászó-Várdomb offer almost no information about daily life at the settlement, investigations in the neighbouring Benta Valley provide relevant data. Based on surveys and cursory settlement data, Kajászó and the Váli Valley fit well in our current understanding of social organisation and regional polities (Earle and Kristiansen 2010; Szeverényi and Kulcsár 2012). Communities in this region inhabited fortified tell and tell-like settlements, densely populated open settlements, small hamlets or farms, and hillforts. Communities also used long-lasting, formal, and bounded areas for disposal of the dead adjacent to their settlements. Numerous settlements and cemeteries along the Danube endured for almost a millennium offering evidence on everyday life and community organisation attesting to an unparalleled sense of history and spatial belonging, and enduring social relations. Such strong transgenerational connection manifested in marked and visible resting places of the ancestors.

Household excavations conducted at the tell settlement of Százhalombatta-Földvár provide relevant information on everyday life (Earle and Kristiansen 2010; Sofaer 2011; Sørensen and Vicze 2013). Houses referencing households and family units were erected over old ones, suggesting stable family 'plots'. Also, the fixed position of hearths throughout multiple house construction phases articulated past and present by the stabilising power of fire. Such durable attachment to place through ancestral links signified and anchored households in space. Fire connected food preparation, feasting, destruction of houses, and construction of ancestors by cremation. Space and place were likely non-discursive indices of social affiliations and identities. Designation of place by burial or funeral pyres and manipulation of spatial relations of burial features likely became operational in mortuary practice.

Analysis of the Benta ceramic economy illuminates regional subsistence and social organisation (Earle *et al.* 2011). First, the relative frequency of storage vessels at settlements implies autonomous communities producing and storing their own staples. Second, patterns of pottery production and consumption indicate localised commodity chains and enduring potting traditions, connecting local potters and neighbouring farmers. Technological and formal considerations suggest that skilled potters purposefully produced distinctive pottery (Budden and Sofaer 2009). Third, there is evidence that houses were decorated with vessels hung on the walls, which suggests that pottery served as a prominent medium of communication. Present in the routines of everyday life that defined identity, relationships, and meaning, local

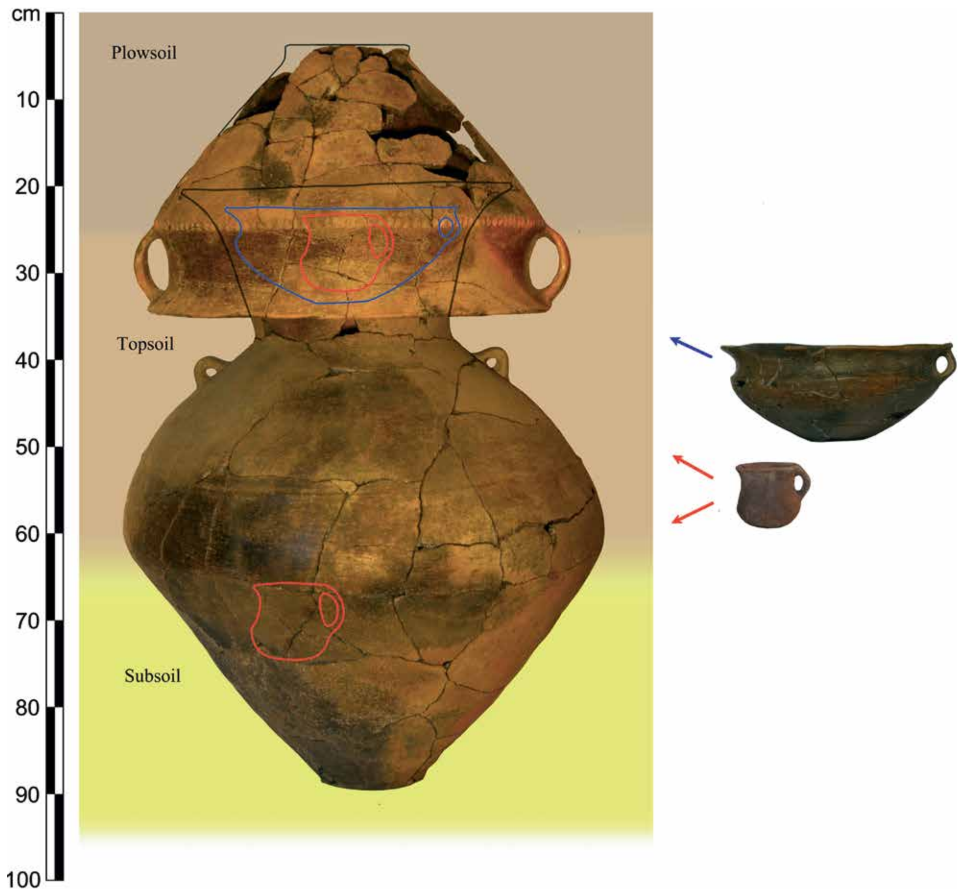

Figure 7. Standardised burial assemblage (illustration by László Gucsi).

pottery was a significant index of community, social relations, and local subsistence (Earle *et al.* 2011). As a manipulable and hard-to-control means of referencing social and economic relations, the role of pottery was likely critical in mortuary practice, which is further accentuated by the strong resemblance between large storage vessels and burial urns, and frequent repurposing of used domestic vessels in the mortuary domain (Polányi 2018, 2022).

Following centuries of stability and sociopolitical reproduction of communities, tell settlements and related cemeteries in the region also attest to a broad sweeping change at the end of the MBA, when most long inhabited tell settlements were reorganised, communities decreased in density, and *all* perpetual cemeteries were abandoned (Vicze 2011). Previous explanations of this transformation referencing large-scale migrations and warfare have been criticised (see Fischl *et al.* 2013; Szeverényi and Kulcsár 2012), however, Bronze Age research still owes a comprehensive account of the process. Settlement pattern analysis along the Benta suggests a complicated narrative characterised by more gradual changes culminating in changing economic and social organisation but continuous occupation of the landscape even after the MBA (Earle and Kristiansen 2010).

Agency and political discourse at Kajászó

Mortuary practice during the EBA III – MBA in central Hungary has been perceived as exceptionally standardised with multiple recurring attributes (see Sørensen and Rebay 2009; Vicze 2011 with extensive list of references). (1) Communities buried most of their dead in spatially defined formal cemeteries. (2) Highly visible, cemeteries were situated in distinctive topographical locations adjacent

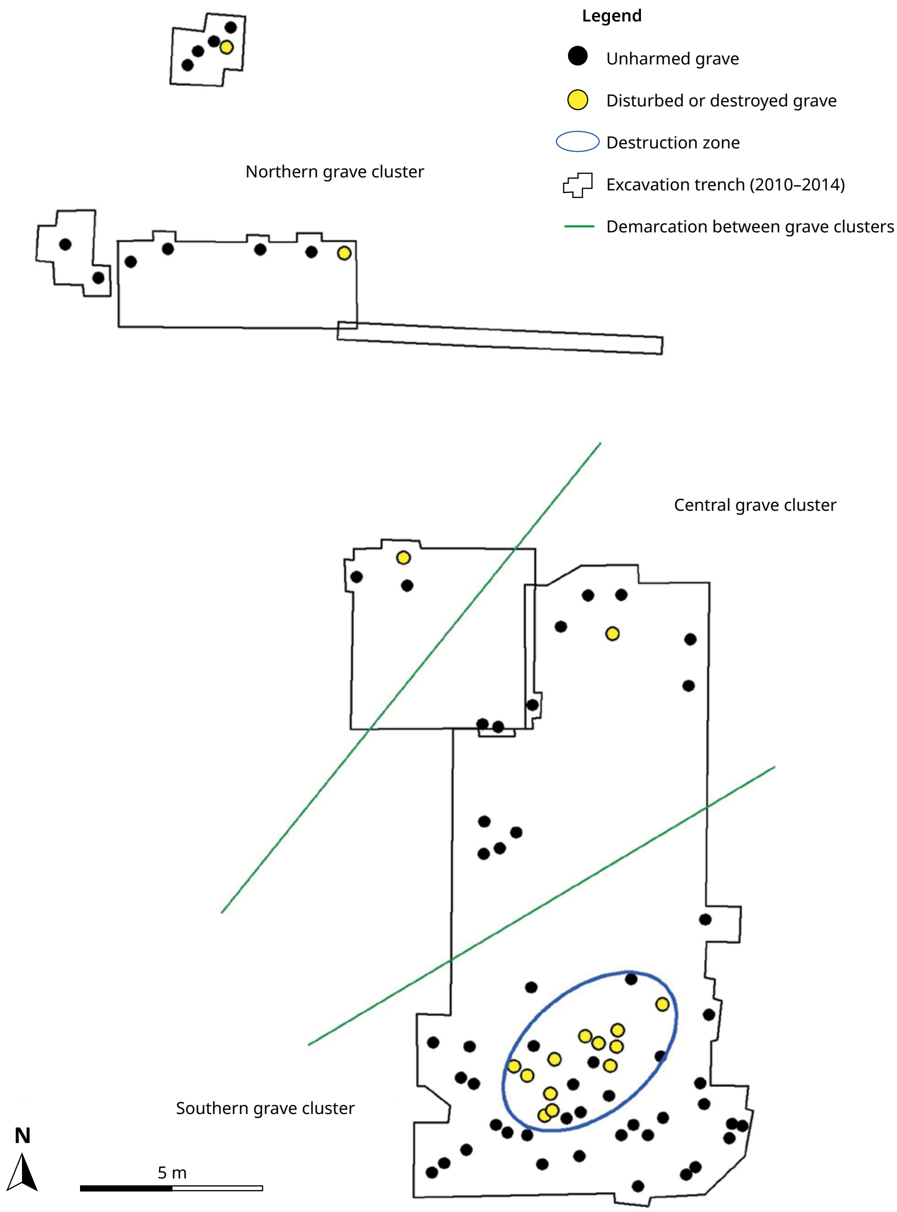

Figure 8. Map of the 'destruction zone' at the Kajászó cemetery.

to settlements. (3) Graves within cemeteries were often ordered within linear or oval-shaped groups of 10 to 15 burials or remained unordered. Grave groups are generally considered to represent kin groups. (4) Grave groups and graves rarely cut into each other suggesting their visibility during the use of the cemetery. (5) Most individuals were cremated, and the cremains were placed in cinerary urns (Fig. 7). (6) Urns were covered with one or two bowls and were often accompanied by a small cup. Urns were buried in a standing position in relatively shallow pits. (7) One or a few pyre locations are found in cemeteries, which were likely used repeatedly throughout the use of cemeteries. At first glance, such level of standardisation of mortuary behaviour would suggest little room for detecting agency and material manifestations of political discourse. Due to our methodological approach placing equal emphasis on grave locations and areas between graves, fragmentation and distribution patterns of pottery, stratigraphic correlations, and use wear, we recovered numerous ways the Kajászó cemetery defies normative descriptions of Vatya mortuary liturgy and expands our understanding of MBA mortuary behaviours

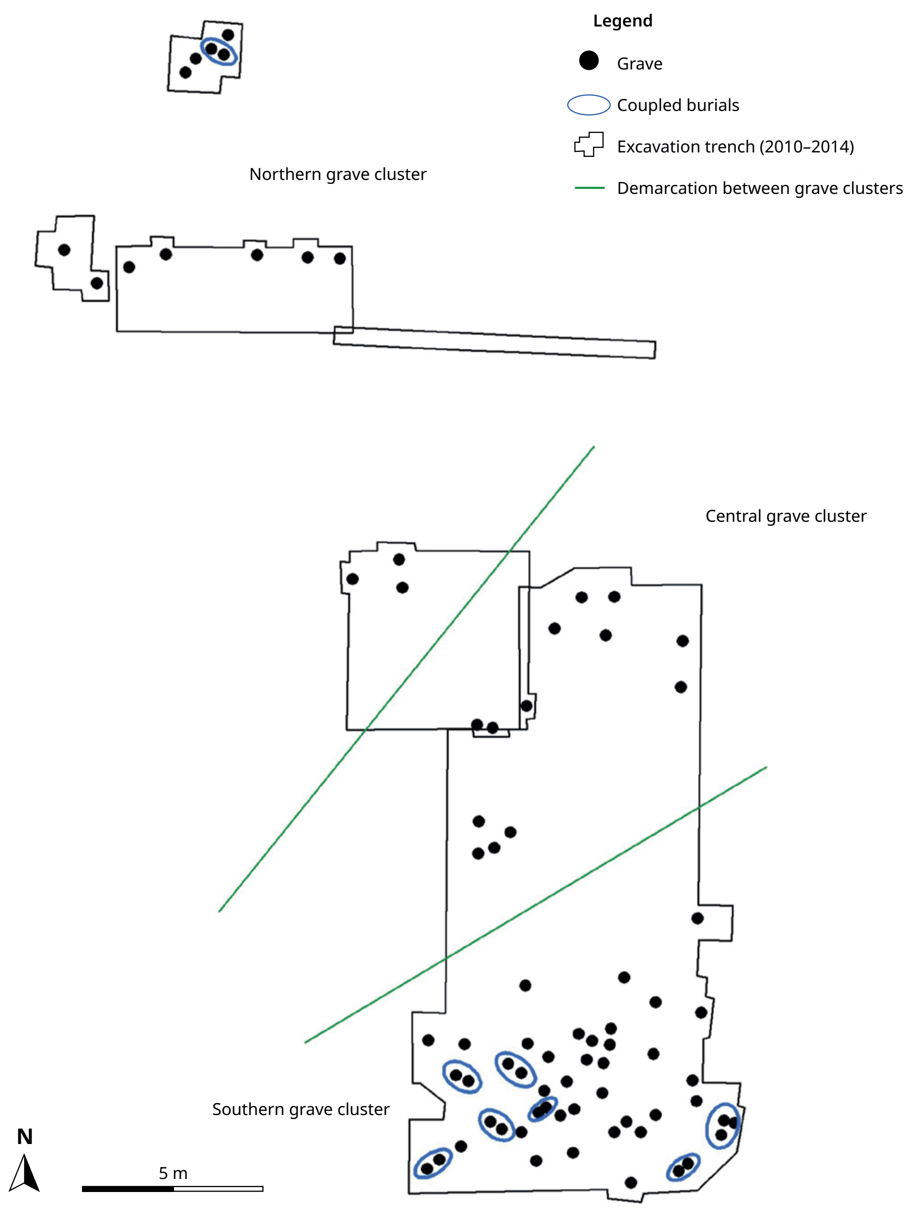

Figure 9. Map of coupled burials at the Kajászó cemetery.

(*e.g.* Polányi 2015, Polányi 2016, Polányi 2018). Here, I will discuss three aspects of mortuary behaviour: contestation of space, creation of spatial/social references, and contingent modification of mortuary behaviours.

The spatial distribution of burials did not follow any regular pattern but evidenced a fierce contestation over particular areas of the cemetery, representing a scramble for 'prime real estate' (Fig. 8). Among the 47 graves detected in the southern grave cluster, we found at least 12 partially or fully destroyed burials – all in a small, ca. 4 m by 3 m area. In each case, large fragments of covering bowls and the cinerary urn were found below to the depth that we identified as the Bronze Age walking surface. In multiple cases, we also found broken pieces of vessels down to the very bottom of once existing burial pits. There was no sign of looting based on our observations during the excavation. Recent destructive activities were ruled out due to the fact that this destruction zone was surrounded by burials with intact covering bowls at a higher elevation.

We also identified a relatively high number of coupled burials (Fig. 9). In the southern grave cluster, we found seven couples, one of which had three touching

Figure 10. Graves 9, 41, and 42 in the southern grave cluster. Photo: T. Polányi.

burials in identifiable stratigraphic relation. The grave triplet (Graves 9, 41, and 42) provide a particularly stark example of the ways in which funeral participants engaged in mortuary practice (Fig. 10). The three graves within the cluster were directly associated with each other. The urn of Grave 9 was touching the cover bowl of Grave 41. The latter vessel was also touching the urn of Grave 42. We could not only identify the stratigraphic sequence of the graves but – based on fragmentation patterns – were able to establish that the burials were not deposited in a quick succession during the same funerary occasion. Some time passed between the deposition of Grave 41 and Grave 9, and at last, the deposition of Grave 42. The primary burial was Grave 41, deposited in the deepest pit at the centre of the cluster. Grave 9 was deposited next, subsequent to a slight collapse of the cover bowl of Grave 41. Grave 42 was deposited on the other side of Grave 41 after its cover bowl collapsed. We also uncovered evidence proving that at the time of the burial of Grave 42, all graves were still visible above the Bronze Age surface.

Grave couples and triplets account for 23% of the total number of excavated burials. The percentage of coupled burials for the southern grave cluster is 32%. Such a large number of spatially associated burials is further emphasised by the fact that during the 2007 excavations at Kajászó, only 6.5% of the burials were coupled. In fact, I have not found coupled burials with comparable frequency in any other Middle Bronze Age Vatya cemetery. Coupled burials included urns and/or covering bowls that showed direct contact upon their deposition also revealing a temporal sequence of the interments. In one case, we found broken pieces of the primary covering bowl from the earlier burial in the bottom of the burial pit of the later burial, suggesting that the earlier burial was accidentally damaged. In almost all cases, earlier burials showed minimal signs of damage despite direct contact between the vessels, seeming to indicate a knowledge of the placement of earlier burials and a directive to establish physical contact.

Figure 11. Grave 28 of the Kajászó cemetery. Photo: T. Polányi.

Finally, the excavation recovered tangible evidence of improvisation and path dependence – modification of mortuary behaviour in response to preceding funerals. The intact assemblage of Grave 28 was found within the destruction zone (Fig. 11). This was one of the two instances when large slabs of stone were placed on top of the grave. Furthermore, the cinerary urn of Grave 28 was the third-largest urn. Despite the huge size of the assemblage, the burial pit was so deep that the flat surface of stone slabs covering the assemblage aligned exactly with the Bronze Age walking surface. Despite its location, all parts of the assemblage were completely intact. All these lines of evidence point towards a conscious choice made by the ritual practitioners to protect that grave, make it invisible, and ensure its perpetuity even though doing so concealed it.

Grave 45, the second burial with a rock covering, was part of the small and isolated burial cluster located between two larger ones. In contrast to Grave 28, Grave 45 did not include an urn or covering bowls, but a small cup placed over a broken base of a large urn located at the bottom of the shallow burial pit (Fig. 12). Three large slabs of rock covered the small amount of cremated human remains scattered in the pit. This reveals an alternative way in which ritual practitioners engaged with the use of rocks as protection or means of differentiation. This constellation of rocks and pottery suggests a completely different narrative compared to that of Grave 28. One potential hypothesis interprets the burial as a reparative attempt. After an initial episode of destruction indicated by the broken base of a large cinerary urn and residual cremated remains, mourners reconstructed the grave by placing a small cup in the damaged pit and covered it with three pieces of rock in an effort to delineate the burial and potentially protect it from subsequent damage. An alternative hypothesis would be an altogether improvised burial event in which mourners intentionally constructed a minimalist burial assemblage marked by the creative use of rock as signifier.

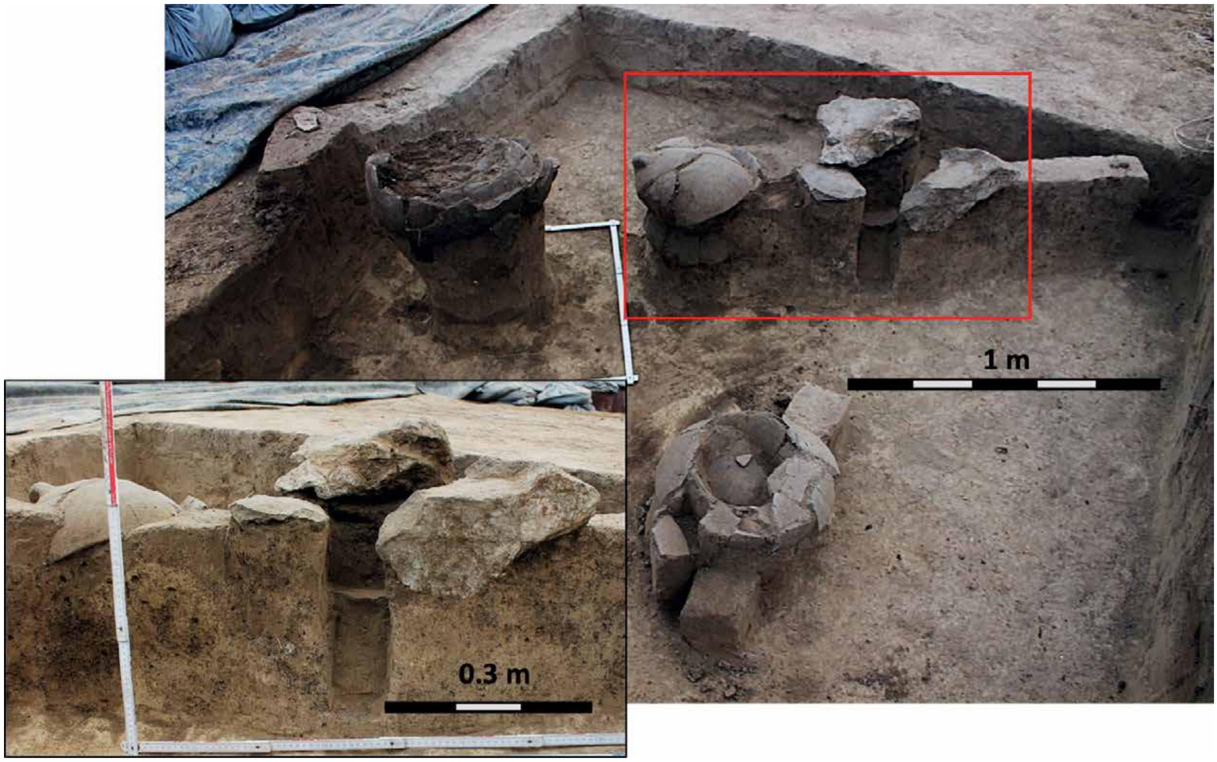

Figure 12. Grave 45 of the Kajászó cemetery. Photo: T. Polányi.

Discussion

Even through this limited glimpse into the cemetery, Kajászó presents exciting and new patterns of mortuary practice that do not conform to previously established patterns of Vatya mortuary behaviours. An immediate explanation may be that this cemetery was unique in some way. It is, however, more likely, that limitations inherent in salvage excavations – which account for overwhelming proportion of BA cremation cemetery excavations – and/or limiting theoretical frameworks that guide research design and implementation (dis)missed significant levels of variability in Vatya mortuary practices. It is, however, striking that based on the 2007 and current excavations, there is significant variability in the use of space and in the ways in which social relations become materialised through burial practice. Despite the relatively large size of exposed surface, burial densities detected in 2007 were nowhere near close to what we saw during the 2013-2014 excavations. Also, careful assessment of the documentation of the 2007 excavation suggests that there was no comparable level of grave destruction either.

The contextual assessment of burial practice – which is hard to establish accurately lacking absolute chronological data – provides an interpretative sphere that can guide our evaluation of the spatial and material practice we recovered in rich detail. Based on the ontologies that define not only the parameters of action, but also the contours of social significance and meaning of materialities of mortuary practice, a sense of belonging to the community and gaining authority or identity through that connection were likely materialised through space by constructing a vertical connection with the ancestors, both metaphorically and physically. This significance of the construction of place was clearly indicated by the destruction zone marking a volatile contestation of identities associated through such vertical connection. The second observation concerns the seemingly haphazard spatial distribution of burials in the southern grave cluster. In contrast, the northern grave cluster – along with distribution patterns detected during the 2007 excavations – indicate an orderly layout. Such discrepancy

in the contestation of space between two adjacent grave clusters is striking and reinforces that there is no singular narrative that can account for the construction of these burial assemblages.

The Kajászó excavation also reveals evidence supporting the conceptualisation of mortuary practice as a sequence of occurrences where mortuary practitioners are fully aware of the preceding burial occurrences and strategically or creatively modify material practices. Burials within the destruction zone indicates one such instance. The use of rock covering in Grave 28 right in the middle of the destruction zone may represent a creative effort to claim authority over the preconditions of membership in a social group expressed through space. However, digging the burial into a deeper pit and covering it with a flat slab of stone aligned with the surface made the assemblage invisible. The claim was seemingly meant to be permanent, but nonetheless represented a compromise in which the grave ceased to serve as a visible reference of exactly the claim secured by its longevity.

Another way in which mortuary participants referenced and drew upon the history of the cemetery was by constructing burials as an extension of existing graves. The grave couples found at high frequency, especially in the southern grave cluster, may indicate an imperative to preserve, amplify, and extend narratives of death initiated at earlier periods. The direct but cautious contact between earlier and later burials is suggestive of the construction of ancestors in reference to more distant ancestors, creating deep genealogies and intensified claims within the cemetery. The one example of a grave triplet (Graves 9, 41 and 42), with two later burials affixed to one predecessor, may signal a lateral extension, or conversely a contestation of one claim with another. In any case, the precision of linking strongly indicates a powerful awareness of and engagement with the cemetery as a continuous site of mindful and intentional activity.

Conclusion

Mortuary evidence presents a narrative of the Kajászó community approaching its disintegration by the end of the MBA as indicated by residues of mortuary behaviour recovered during the 2013-2014 excavation campaign. Cacophony of mortuary practice, a clear shift in the use of space compared to earlier periods of the cemetery, increased level of engagement through hard-to-control means of differentiation are likely manifestations of volatile political discourse about community cohesion and corporate identities. However, the case study presented is merely an approximation of the resolution of political discourse necessary to illuminate the processes that precipitated the dissolution of the Kajászó community and regional polities. Increasing the sample size of mortuary analysis, rigorous application of radiocarbon dating, and simultaneous investigation of domains of everyday life would likely bring us closer to materialise the full potential of the presented approach to funerals as circuits of reproduction. Instead, within the limitations of this article, my goal was to underline the capacity of this approach to detect human agency and political discourse in creative and contingent manipulation and deployment of culturally available repertoires of material practice. Such idiosyncrasies of human – material interaction are rarely detected due to archaeological formation processes, or often become discarded as noise vis-à-vis more robust and cumulative material traces of repetitive behaviours. The mortuary domain, however, is more likely to present fortunate circumstances that both preserve and contextualise such residualities providing a glimpse into political discourse and social change and persistence on a human-scale.

On a more abstract level, I aimed to explore the recursive relationship between how people perceive history and the ways in which archaeologists construct narratives of the past. I find that our limitation to comprehend history in the present or, more specifically, to comprehend processes precipitating sweeping social changes

manifest in presumed epistemological limitations of archaeology. Such pessimistic outlook considers archaeology unlikely to ever achieve the temporal resolution required to expose unfolding sequences of actions that make up an historical event, or to ascertain the efficacy of human agency and its role in precipitating and directing broad social transformations (*e.g.* Bolender, 2010, 8; Hodder 2000, 31; Hodder, 2016, 26). In contrast, I argue, the explosion of high-resolution empirical data on contemporary political discourse offers an extraordinary resource to better understand and conceptualise mechanisms of social change and persistence, which, in turn, can contribute to refined analytical approaches to historical transformations. On the other hand, archaeology has the capacity to identify and assess materialities of interpersonal interactions within almost unlimited iterations of historical settings offering a unique perspective to illuminate current processes of political discourse and to improve our understanding of change and – sometimes inexplicable – instances of stasis in modern society.

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This paper emerged from the profound sadness and bewilderment I felt again and again following the Sandy Hook Elementary School shooting in late 2012. It is my incomplete and insufficient response to the perplexing and infuriating resistance to and refusal of a society to commit to institutional change to curtail the rampant gun violence in the United States. This paper also reflects my conviction that anthropology and, more specifically, anthropological archaeology can foster and shape our understanding of the mechanisms of social change and persistence. I am grateful for the editors of this volume for inviting me to contribute, and for their continued support throughout the review process. I would like to thank the anonymous peer reviewers for their helpful comments, which significantly improved the manuscript. Any remaining errors are my own.

References

Beck Jr, R.A., Bolender, D.J., Brown, J.A. and Earle, T.K., 2007. Eventful Archaeology: The Place of Space in Structural Transformation. *Current Anthropology*, 48 (6), 833-60.

Bolender, D.J, 2010. Introduction: Toward an Eventful Archaeology. *In:* D.J. Bolender, ed. *Eventful Archaeologies: New Approaches to Social Transformation in the Archaeological Record*. Albany: State University of New York Press, 3-14.

Bourdieu, P., 1977. *Outline of a Theory of Practice*. Cambridge: Cambridge University Press.

Brady, H.E., 2019. The challenge of big data and data science. *Annual review of Political Science* 22, 297-323.

Bromwich, J.E., 2018. How the Parkland Students Got So Good at Social Media. *The New York Times*, 7 March. Available from: https://www.nytimes.com/2018/03/07/us/parkland-students-social-media.html [Accessed 7 Nov 2022]

Brumfiel, E.M., 2011. Towards a middle range theory of household politics: The standardization of decorative motifs in Middle Postclassic Mexico. *In:* P. Johansen and A.M. Bauer, eds. *The Archaeology of Politics: The Materiality of Political Practice and Action in the Past*. Newcastle upon Tyne: Cambridge Scholars, 245-282.

Budden, S. and Sofaer, J., 2009. Non-discursive knowledge and the construction of identity. Potters, potting and performance at the Bronze Age Tell of Százhalombatta, Hungary. *Cambridge Archaeological Journal*, 19 (2), 203-220.

Canuto, M.-A. and Yaeger, J. eds., 2000. *The Archaeology of Communities. A New World Perspective*. London: Routledge.

Comaroff, J. and Comaroff, J.L., 1991. *Of Revelation and Revolution*. Chicago: University of Chicago Press.

Earle, T., 2002. *Bronze Age Economics: The Beginnings of Political Economies*. Boulder, Colo.: Westview Press.

Earle, T., 2003. Anthropology must have archaeology. *In:* S. Gillespie and D. Nichols, eds. *Archaeology is Anthropology*. Washington, D.C.: AAA, 17-26.

Earle, T., 2004. Culture Matters in Neolithic Transition and Emergence of Hierarchy in Thy, Denmark. *American Anthropologist* 106, 111-125.

Earle, T., 2013. The 3M: Materiality, materialism, and materialization. *In:* S. Bergerbrant and S. Sabatini, eds. *Counterpoint; Essays in Archaeology and Heritage Studies in Honour of Professor Kristian Kristiansen.* Oxford: BAR International Series 2508, 353-360.

Earle, T.K, and Kristiansen, K., 2010. *Organizing Bronze Age societies: the Mediterranean, central Europe, and Scandinavia compared*. New York: Cambridge University Press.

Earle, T., Kreiter, A., Klehm, C., Fergusson, J. and Vicze, V., 2011. Bronze Age ceramic economy: The Benta Valley, Hungary. *European Journal of Archaeology* 14 (3), 419-440.

Fischl P., K., Kiss, V., Kulcsár, G., Szeverényi, V., 2013. Transformations in the Carpathian

Basin around 1600 B.C. *In:* H. Meller, F. Bertemes, H-L. Bork, R. Risch eds. *1600 – Kultureller Umbruch im Schatten des Thera-Ausbruchs? 4. Mitteldeutscher Archäologentag vom 14. Bis 16. Oktober 2011 in Halle (Saale)*. Halle: Landesamt für Denkmalpflege und Archäologie Sachen-Anhalt, 355-371.

Fowler, G.A., 2018. They survived a school shooting only to wage battle in some of the nastiest corners of the internet. *The Washington Post*, 8 March. Available from: https://www.washingtonpost.com/news/the-switch/wp/2018/03/08/the-parkland-survivors-are-children-remember-that-when-they-go-viral/ [Accessed 7 Nov 2022]

Gallup, 2022. *Guns*. Available from: https://news.gallup.com/poll/1645/guns.aspx [Accessed 7 Nov 2022]

Geertz, C., 1980. *Negara: The Theatre State in Nineteenth-Century Bali*. Princeton, NJ: Princeton University Press.

Giddens, A., 1984. *The Constitution of Society: Outline of Structuration*. Cambridge: Polity Press.

Gramsci, A., Hoare, Q. and Smith, G., 1971. *Quaderni del Carcere. Selections from the Prison Notebooks of Antonio Gramsci.* Edited and Translated by Quintin Hoare and Geoffrey Nowell Smith. London: Lawrence & Wishart.

Granka, L., 2013. Using Online Search Traffic to Predict US Presidential Elections. *Political Science and Politics* 46 (2), 271-279.

Google Trends, 2018. *Gun control.* Available from: https://trends.google.com/trends/explore?q=gun%20control&geo=US [Accessed 26 Apr 2018]

Hauser, M.W., 2008. *An Archaeology of Black Markets: Local Ceramics and Economies in Eighteenth-Century Jamaica*. Gainesville, FL: University Press of Florida.

Hodder, I., 2000. Agency and Individuals in Long-Term Processes. *In:* M-A. Dobres and J.E. Robb, eds. *Agency in Archaeology*. London: Routledge, 21-33.

Hodder, I., 2016. *Studies in Human-Thing Entanglement*. Stanford, California.

Johansen, P.G. and Bauer, A.M., 2011. *The Archaeology of Politics: The Materiality of Political Practice and Action in the Past*. Newcastle upon Tyne: Cambridge Scholars.

Johnson, M.H., 2000. Conceptions of Agency in Archaeological Interpretation. *In:* J. Thomas, ed. *Interpretive Archaeology: A Reader*. London, New York: Leicester University Press, 211-227.

Kaye, B.K. and Johnson, T.J., 2002. Online and in the know: Uses and gratifications of the web for political information. *Journal of Broadcasting and Electronic Media* 46 (1), 54-71.

Keane, W., 2010. Marked, absent, habitual: Approaches to Neolithic religion at *Çatalhöyük*. *In:* I. Hodder, ed. *Religion in the emergence of civilization: Çatalhöyük as a case study*. Cambridge: Cambridge University Press, 187-219.

Kiss, V., 2011. The Role of the Danube in the Early and Middle Bronze Age of the Carpathian Basin. *In:* G. Kovács and G. Kulcsár, eds. *Ten thousand years along the Middle Danube: Life and Early Communities from Prehistory to History*. Budapest: Archaeolingua, 211-239.

Kiss, V., Csányi, M., Dani, J., Fischl P., K., Kulcsár, G., 2019. Chronology of the Early and Middle Bronze Age in Hungary. New results. *Studia. Hercynia* XXIII/2, 173-197.

Kosoff, M., 2018. 'Anger and hope': Why the Parkland survivors are winning the social-media war. *Vanity Fair*, 20 February. Available from: https://www.vanityfair.com/news/2018/02/parkland-students-shooting-survivors-social-media [Accessed 7 Nov 2022]

Kovács L.O., 2008. Kajászó, Keskeny-Dűlő. *Régészeti Kutatások Magyarországon – Archaeological Investigations in Hungary* 2007, 232-233.

Kovács T., 1969. A Százhalombattai Bronzkori Telep. The Bronze Age settlement at Százhalombatta. *Archaeológiai* Értesítő 96, 161-169.

Kristiansen, K., 2008. Do we need the 'archaeology of Europe'? *Archaeological Dialogues* 15 (1), 5-25.

Laabs, J., 2013. *Das Gräberfeld von Dunaújváros-Dunadűlő und die Mittlere Bronzezeit im zentralen Karpatenbecken: Untersuchungen zu Chronologie und Bestattungssitte*. Christian-Albrechts-Universität zu Kiel. Unpublished master's thesis.

Mahoney, J., 2000. Path dependence in historical sociology. *Theory and Society* 29 (4), 507-548.

Miller, D., 2005. Materiality: An Introduction. *In:* D. Miller, ed. *Materiality*. Durham, NC: Duke University Press, 1-50.

Nováki G., 2004. Kajászó, Várdomb. *Régészeti Kutatások Magyarországon – Archaeological Investigations in Hungary* 2003, 234.

Ohlheiser, A. and Epstein, K., 2018. Just try to keep calm: How one Parkland student's phone became his lifeline, and his voice. *The Washington Post*, 3 March. Available from: https://www.washingtonpost.com/graphics/2018/lifestyle/parkland-shooting-in-social-media/?tid=ss_mail [Accessed 7 Nov 2022]

Ortner, S.B., 1984. Theory in Anthropology since the Sixties. *Comparative Studies in Society and History 26, 126-166.*

Parmentier, R.J., 1987. *The Sacred Remains: Myth, History, and Polity in Belau*. Chicago: University of Chicago Press.

Pels, P., 2010. Temporalities of Religion at *Çatalhöyük*. *In:* I. Hodder, ed. *Religion in the emergence of civilization: Çatalhöyük as a case study*. Cambridge: Cambridge University Press, 220-267.

Polányi, T., 2010. *Preliminary report on the 2010 survey and test excavation at Kajászó-Keskeny dűlő, Hungary.* Report submitted to the Hungarian National Museum and to the Hungarian Academy of Sciences. Northwestern University.

Polányi, T., 2014. *Preliminary report on the survey and excavation of the Bronze Age cemetery of Kajászó-Keskeny dűlő during the 2013-2014 field seasons*. Report submitted to the Hungarian National Museum and to the Hungarian Academy of Sciences. Northwestern University.

Polányi, T., 2015. Death politics: A micro-archaeological analysis of Bronze Age burials at Kajászó, Hungary. *In: 114th Annual Meeting: 'Familiar strange'*. Arlington: American Anthropological Association, 434-434.

Polányi, T., 2016. One burial at a time: Integrating eventful archaeology and mortuary analysis. *In: 22nd Annual Meeting of the EAA – Abstracts*. Klaipėda: Saulius Jokuzys Publishing, 135-135.

Polányi, T., 2018. *Narratives of death: Social change and funerary practice at the Bronze Age cemetery of Kajászó, Hungary. Northwestern University*. ProQuest Dissertation Publishing, 10822065.
Polányi, T., 2022. The rise of *idiôtês*: Micro-politics of death and community reproduction in Bronze Age Hungary. *Journal of Anthropological Archaeology* 68, 101445.
Preucel, R.W., 2006. *Archaeological Semiotics*. Malden, MA: Blackwell.
Robertson, S.P., 2018. *Social media and civic engagement: history, theory, and practice.* Morgan & Claypool.
Roseberry, W., 1989. *Anthropologies and Histories: Essays in Culture, History, and Political Economy*. New Brunswick; London: Rutgers University Press.
Rowlands, M., 2005. A Materialist Approach to Materiality. *In:* D. Miller, ed. *Materiality*. Durham, NC: Duke University Press, 72-87.
Sahlins, M.D., 1985. *Islands of History*. Chicago; London: University of Chicago Press.
Sahlins, M.D., 2002. *Waiting for Foucault, still*. Chicago: Paradigm Press.
Schug, G.W., 2020. Indus Mortuary Behavior: Between action and symbolic meaning. *In:* Shirvalkar, P., Prasad, E., eds. *Pratnamani: Felicitation Volume for Professor Vasant Shinde*. Deccan: Deccan College Post-Graduate Research Institute Press.
Sewell, W.H., 2005. *Logics of History: Social Theory and Social Transformation*. Chicago, IL: University of Chicago Press.
Sherratt, A., 1993. What Would a Bronze-Age World System Look Like? Relations Between Temperate Europe and the Mediterranean in Later Prehistory. *Journal of European Archaeology Journal of European Archaeology,* 1 (2), 1-58.
Sofaer, J., 2011. Human Ontogeny and Material Change at the Bronze Age Tell of Százhalombatta, Hungary. *Cambridge Archaeological Journal*, 21 (2), 217-227.
Sørensen, M.L.S, Rebay-Salisbury, K., 2009. Landscapes of the body: Burials of the Middle Bronze Age in Hungary. *European Journal of Archaeology*, 11 (1), 49-74.
Sørensen, M.L. and Vicze, M., 2013. Locating Household Activities on a Bronze Age tell. *In:* M. Marco, G. Kovács, B. Kulcsárné-Berzsenyi, and I. Briz Godino, eds. *The Archaeology of Household*. Oxbow Books.
Statista, 2022. *Number of victims of the worst mass shootings in the United States between 1982 and May 2022*. Available from: https://www.statista.com/statistics/476101/worst-mass-shootings-in-the-us/ [Accessed 7 Nov 2022]
Szeverényi V. and Kulcsár, G., 2012. Middle Bronze Age Settlement and Society in central Hungary. *In:* M. Jaeger, J. Czebreszuk, and Fischl P., K., eds. *Enclosed space – open society: contact and exchange in the context of Bronze Age fortified settlements in central Europe*. Studien zur Archäologie in Ostmitteleuropa 9. Poznań and Bonn: Dr. Rudolf Habelt GmbH, 287-351.
Turner, V.W., 1969. *The Ritual Process: Structure and Anti-Structure.* Chicago: Aldine Publishing Company.
van Gennep, A., 1909. *The Rites of Passage*. Chicago: University of Chicago Press.
Vicze, M., 2011. *Bronze Age cemetery at Dunaújváros-Duna-dűlő*. Dissertationes Pannonicae Ser. IV, Vol. 1. Budapest: Eötvös Loránd University, Institute of Archaeological Sciences.
Wells, E.C., 2006. Recent trends in theorizing Prehispanic Mesoamerican economies. *Journal of Archaeological Research*, 14, 265-312.
Wells, E.C. and Davis-Salazar, K.L., eds., 2007. *Mesoamerican ritual economy: Archaeological and ethnological perspectives*. Boulder, CO: University Press of Colorado.
Wells, E.C. and McAnany, P.A., eds., 2008. *Dimensions of Ritual Economy*. Bingley: Emerald.
Wolf, E., 1982. *Europe and the people without history*. Los Angeles: University of California Press.

Applying the Inequality Possibility Frontier and the Inequality Extraction Ratio to archaeological data: Studying inequality in the Early Bronze Age cemetery of Jelšovce (Slovakia)

Fynn Wilkes, Henry Skorna

Abstract

The study of social inequality in prehistoric societies often relies on quantitative methods. One prominent tool is the Gini index, which measures inequality (*i.e.* wealth) within a distribution (*i.e.* society). However, this relatively simple measure does not consider the economic limitations in pre-industrial or less developed societies. Over the course of the past 20 years, B. Milanovic developed the concept of the Inequality Possibility Frontier and the Inequality Extraction Ratio. With the help of these methods, the measured inequality (*e.g.* in the form of the Gini index) can be considered in relation to the maximum possible inequality. Further, economic limitations and possible causes for inequality can be discussed. Both methods – the Inequality Possibility Frontier and the Inequality Extraction Ratio – are presented in this paper and applied and discussed in relation to the example of the cemetery of Jelšovce (Slovakia). We show that in this way, a more differentiated picture of prehistoric social inequality can be obtained, which then can be discussed in the light of contemporary societal developments such as the development of settlements and the presence of traumata in society. Further, this study shows the movement of wealth between different phases of the Early Bronze Age and between different social groups.

Keywords: *social archaeology, social inequality, Inequality Possibility Frontier, burial archaeology, Gini index*

Quantitative inequality measures in archaeology

Social inequality or wealth disparities within prehistoric societies have become central topics of archaeological research in recent years (Porčić 2012; Siklósi 2013; Windler *et al.* 2013; Arponen *et al.* 2016; Kohler *et al.* 2017; Fochesato *et al.* 2019; Porčić 2019; Ames and Grier 2020; Basri and Lawrence 2020; Grossmann 2021; Kerig *et al.* 2022). Several studies approach the topic with quantitative methods, borrowed from economic and sociological research. At the centre of many studies is the Gini coefficient (see Kerig *et al.* 2022 for a detailed description), an established measure of inequality that measures the extent to which the distribution (*e.g.* of wealth) within an economy deviates from an equal distribution (Requate 2023). Usually the index ranges from 0 to 1, with 0 indicating total equality and 1 indicating total inequality (Kerig *et al.* 2022).

Recently, the methodological tools of historical economics and social archaeology have been complemented by the concept of the Inequality Possibility Frontier (IPF) and the Inequality Extraction Ratio (IER) to analyse developments in pre-industrial societies (Milanovic 2006; Milanovic *et al.* 2007; Milanovic 2009; Milanovic *et al.* 2011; Milanovic 2013; Kerig *et al.* 2022). Using the Early Bronze Age cemetery of Jelšovce (Nitra district, Slovakia) as a case study, we use the IPF and the IER to examine the additional value of these methods when considering prehistoric societies.

The Inequality Possibility Frontier and the Inequality Extraction Ratio

The IPF[1] was first presented by Branko Milanovic (Milanovic 2006) and further elaborated by Milanovic, Peter Lindert and Jeffrey Williamson (2007). In his study of income and inequality in Byzantium (*ca.* 1000 AD), Milanovic (2006) scrutinised the applicability of measures of inequality, such as the Gini index, on pre-industrial societies and their comparability across time. This work demonstrated that in many less developed or pre-industrial societies, due to economic limitations, the upper limit of possible inequality is not at a Gini index of 1 (or 100%) but, instead, at an index of lower than 1 (Milanovic 2006, 466; Milanovic *et al.* 2011, 264).

This investigation precipitated the development of a more refined methodology: the IPF (Fig. 1; Milanovic 2006; Milanovic *et al.* 2011).

Rather than simply comparing Gini indices, the IPF results from the calculation of the Maximum Feasible Inequality (MFI) and indicates the upper limit of feasible inequality (in the form of a Maximum Feasible Gini Index (MFG); Milanovic *et al.* 2011, 258) when the ratio of average wealth as a multiple of the subsistence minimum increases. It defines a measured inequality upper border considering the subsistence minimum and the average income or wealth within a society, as well as the share of a possible elite. Milanovic describes the IPF as 'the maximum Gini that is achievable at a given level of mean income provided that all population but an infinitesimally small elite live at least at the subsistence minimum' (Milanovic 2009, 15). The IPF therefore produces a value that scales the measured, or observed, Gini indices within a society in relation to its socio-economic capabilities. The following assumptions are made while calculating the IPF (Milanovic *et al.* 2007; Milanovic 2009):

1 Abbreviations in the Text: IER: Inequality Extraction Ratio; IP: Index Points; IPF: Inequality Possibility Frontier; MFG: Maximum Feasible Gini; MFI: Maximum Feasible Inequality; mG: measured Gini; mI: measured Inequality

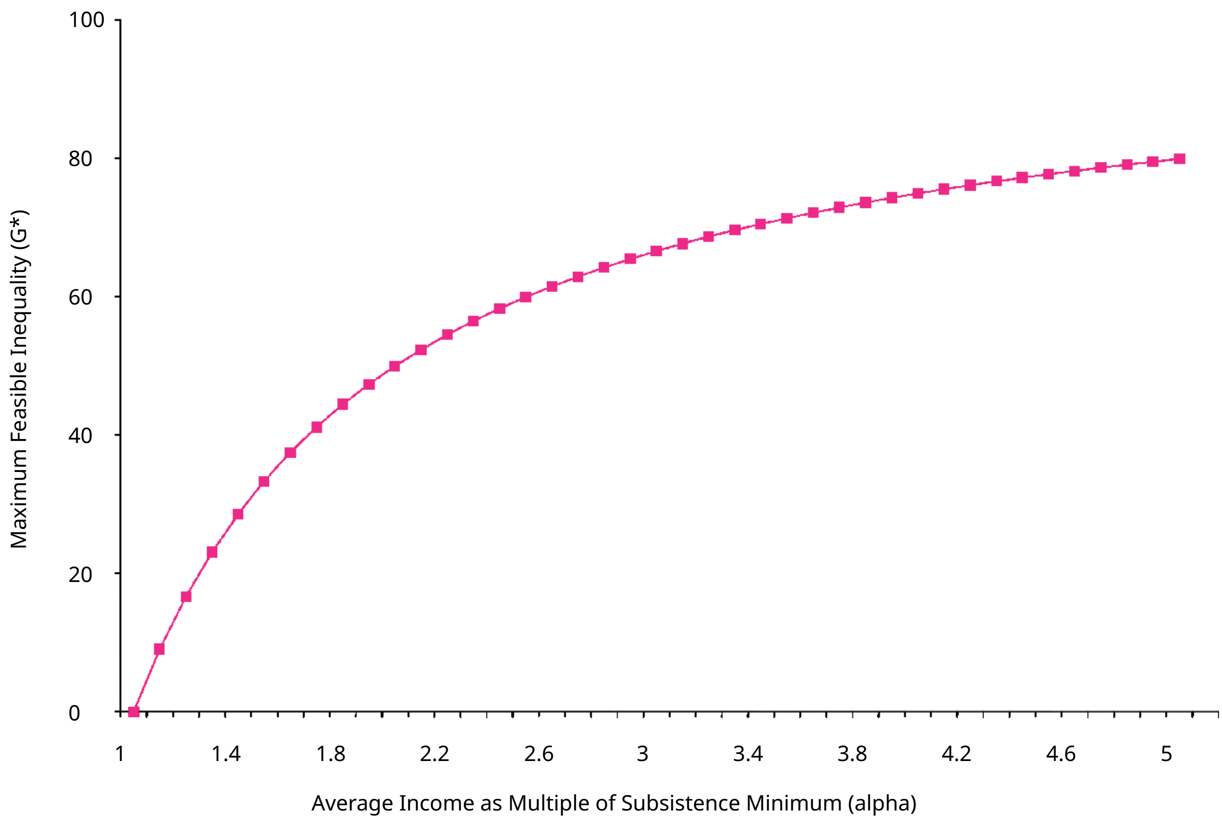

Figure 1. Inequality Possibility Frontier visualised, showing that the maximum feasible inequality (Gini index) is an increasing function of mean overall income (Milanovic et al. 2007, 7, 2011, Fig. 1).

- Societies (normally) distribute their wealth in such a way that it ensures at least survival (physiological subsistence minimum) for their poorest members, otherwise the society dies (Milanovic et al., 2007, p. 6ff.)
- All wealth that exceeds the subsistence minimum is available as surplus and can be exploited by the most influential members (elite) of a society (Milanovic et al., 2007, p. 7).

The IPF is based on the calculation of the MFI, in its simplest form, this can be calculated using the example of a society roughly divided into two groups - rich and poor. In this case, the MFI is calculated as follows:

$$MFI = \frac{\alpha - 1}{\alpha}(1 - \varepsilon)$$

$$\alpha = \frac{m}{s}$$

where α is the ratio of average wealth (m) to subsistence minimum (s) and ε is the share of wealth controlled by the economically advantaged group in the society (Milanovic's 'elite').

Milanovic *et al.* (2007, 9f.) concluded that the share of the elite (ε) has a small effect on the MFI, which is why the formula can be simplified for an assumed small share of an elite in the total society (share tends to zero), as follows:

$$MFI = \frac{\alpha - 1}{\alpha}$$

In a more recent work, Milanovic argues for a social minimum as opposed to a subsistence minimum (Milanovic 2013, 5). Milanovic shows that in the present day, the subsistence minimum is only influential on less developed societies. In the majority of modern societies, the focus is less on survival and more on social participation. Therefore he modified the MFI calculation for developed societies by introducing a social minimum as a flexible lower limit (Milanovic 2013, 6). Usually, the MFI expresses an MFG that can be compared with a Gini index that has been measured on a sample of a society (mG).

Based on the MFI, Milanovic developed another measure: the IER (2009). The IER is the ratio between the measured (observed) inequality and the MFI.

$$IER = \frac{ml}{MFI}$$

where mI=measured inequality; MFI=maximum feasible inequality.

This ratio primarily expresses the share of surplus (wealth) extracted by an already wealthy group. Higher values show a higher success of the elite in extracting the economic surplus. If the IER exceeds 1 (or 100%), both the surplus and part of the wealth needed for survival are extracted from a society, which will lead to its decline in the mid- to long term (Milanovic 2009, 16). Milanovic (2013, 4) shows that the IER also works as a measure of the level of economic development, since less developed societies tend to produce a smaller surplus and therefore show higher IERs. Furthermore, there is a link between the IER and the duration and fatality of civil conflicts (Milanovic 2013).

Archaeological application: methodology and methodological considerations

The primary benefit of IPF and MFI over the Gini index for prehistoric research is that they provide a tool to meaningfully assess inequality measures between societies with different economic strategies (*e.g.* pastoralism *vs.* farming) and occurring during different time periods (*e.g.* Neolithic and Bronze Age). The secondary benefit is that the IER allows us to make statements about the economic role of a possible elite within a society. By calculating the IER for various periods, it is possible to track whether the distribution of wealth and economic surplus is trending towards exploitation by elites or is retained by the wider society. By comparing the MFG to the measured Gini, we may draw conclusions about the economic capabilities of a society to generate a surplus that can be exploited by an elite or that, instead, is accessible to a wider group.

The main challenge in using quantitative inequality measures on archaeological datasets is the availability of the data and their quality. The Gini index is often determined using income or wealth data (Xu 2003, 4), usually on easily measurable variables, such as household income or Gross Domestic Product. Among prehistoric societies, however, we have no data on income or even what value archaeological objects had. Two approaches have gained recognition for the quantification of wealth in prehistoric societies. House sizes are a well-established approach to determining wealth in prehistoric groups (*e.g.* Kohler *et al.* 2017; Porčić 2019; Basri and Lawrence 2020; Kerig *et al.* 2022) but rely on large settlement excavations. Graves present a somewhat more accessible alternative, due to their smaller size and the better availability of grave data. Incorporating burials into inequality calculations requires the determination of a grave index that can be incorporated in inequality calculations (*e.g.* Windler *et al.* 2013; Grossmann 2021). These grave indices include various factors, such as grave architecture or the frequency and

quantity of grave goods. As of yet, a uniform grave index has not been supported by the literature; instead indices are adapted to the respective datasets and archaeological contexts (for example, Holten 1989; Hedeager 1990; Müller 1994; Rebay-Salisbury 2006; Bösel 2008; Beyer 2020).

To calculate a Gini index for burials, a burial index serves as a measure of the value of artefacts. Simply put, since we do not have income data that measures wealth in monetary currency, we must implement a quantifiable proxy (*i.e.* grave index points). We note that, in addition to wealth, grave goods also can reflect the social status of the buried person. Wealth and social status most certainly correlate with each other, although the extent of this correlation remains unknown. This correlation applies to all archaeological analysis looking at prehistoric inequality while using statistics, whether the used data derive from grave goods or from something else, such as house size. We assume here that, in order to display a higher social status, a higher economic capability is needed. For example, for building a bigger house (access to) more resources, and more labour are needed. Following the oft-used phrase 'The dead don't bury themselves' when dealing with graves, we are looking not only purely at individual wealth but most likely at the economic capability of a household or social group displayed within the burial. While inequality measures, such as the Gini index, have been successfully integrated into archaeological datasets, applying the calculation of the MFI and IER on burial data adds a substantial level of complexity.

In order to calculate the MFI, it is necessary to define the subsistence level – that is, the lowest level of income or wealth necessary to ensure survival – within the society. A subsistence minimum using a modern analogy – such as the value of a shopping basket filled with the minimum amount of goods for physiological survival (survival minimum expenditure basket: 2100 kcal; World Food Programme) – cannot usually be defined in archaeological contexts. For this reason, other indicators are necessary to define a subsistence minimum or a social minimum (the latter being the minimum surplus value needed to enable social participation). In a study on inequality on the Ovčarovo and Poljanica tell settlements (both Targovishte district, Bulgaria), we used the size of the smallest house of a settlement phase to define the social minimum (Kerig *et al.* 2022).

In cemeteries such as Jelšovce (Bátora 2000a), which is used here as an example, a wide range of information on the individual burials is available. On the basis of the anthropological analysis, grave goods and grave architecture, we have determined a grave index value for each time period of the burial ground that represents the subsistence or social minimum, although we cannot be certain whether the data from cemeteries refer to a social or subsistence minimum. Our approach takes up the idea of a minimum wealth for reaching an old age (subsistence minimum, see below). The entire analysis is carried out under a number of basic assumptions and is intended as a model approach to implement for the MFI and IER analyses on burial data.

The five basic assumptions are as follows: (1) The burial community under consideration at the Jelšovce cemetery represents a closed society (*e.g.* the population of one village) or at least a representative sample of the local Early Bronze Age (EBA) society. (2) The graves, their grave goods and their funerary architecture are an expression of the wealth of the buried person or the group who buried the individual (*e.g.* family, household, clan). (3) A possible very wealthy and exploiting social group (Milanovic's 'elite') makes up a very small part within the society (see above). (4) The average wealth of a cemetery phase is the average wealth of all deceased persons regardless of age groups. (5) The subsistence minimum is defined as the mean wealth of the 10% poorest individuals from the *maturus* and *senilis* age groups. This approach is based on the consideration that in relation to life expectancy in Bronze Age societies, which for Hungary is 24-32 years (Ubelaker

and Pap 1996, 292) and for Jelšovce is 38-41 years (Koel 2011, 222), the grave index of individuals in the *maturus* and *senilis* age groups is indicative of what level of wealth is necessary to reach this life expectancy with certainty. We assume that younger wealthy deceased persons died due to extreme external factors (*e.g.* illness, violence, accident). Instead of choosing only the grave index value of the poorest burial in this age group, we chose to take the mean of the poorest 10%. This way we avoided relying too much on a single burial that may represent an unrecognised disturbed grave or an outlier.

As described above, using a modelled subsistence minimum over a defined value of calories is necessary since we lack information about the calorie production and intake in almost every prehistoric period. This approach is open to discussion, but in our opinion is justifiable because our intention is to define a value that indicates the wealth needed to meet the basic needs within a society. We argue that it is not enough to simply set a fixed value, because the wealth necessary meet a subsistence minimum can change between societies and time periods. In contrast to an approach employing a constant subsistence minimum, our approach leads to a flexible value that can vary in individual grave groups and time phases, allowing us not only to make a statement about the economic power of a population through the ratio of subsistence minimum to average wealth (α), but also to consider the subsistence minimum independently. A higher subsistence minimum value may indicate a less efficient form of economic activity, since more wealth must be accumulated to ensure survival, whereas lower subsistence minimum values show that the physiological minimum can already be achieved with little effort. This approach varies from that of Milanovic, Lindert and Williamson (2007, 7) and conforms to the idea of a flexible social minimum (Milanovic 2013). This is relevant in our application because the MFI is not simply an increasing function of mean overall income but is now bound to an increasing mean overall income in relation to a small subsistence minimum.

For the analysis, we calculated grave indices from grave goods and grave depth using the method of Z-transformation, hereinafter referred to as index points (IP) (for the detailed methodology, see Wilkes and Skorna 2022; Bösel 2008). We included only undisturbed burials in the calculation of the Gini index, subsistence minimum, and average wealth analysis.

Due to the custom of re-opening graves, especially within the later Únětice and Mad'arove burial group, it could be argued that wealthier graves might be underrepresented, as they would have been the primary targets if economic gain was the underlying motivation for the re-opening. However, Müller-Scheeßel *et al.* (2020) are arguing, for the nearby EBA settlement and burial site of Vráble 'Fidvár' (Žitava Valley, Nitra district, Slovakia), that the re-opening (and removal of some of the grave goods) by a later population of the settlement is an act to ensure that no-one would confuse those buried in the cemetery with their own ancestors. This is supported by the fact that grave goods with possibly high symbolic and valuable goods, such as golden earrings or bronze jewellery, were left in the graves (Müller-Scheeßel *et al.* 2020, 201). As this pattern is also seen at Jelšovce, wealthier graves are most likely not underrepresented in the dataset. We included all age groups in the analysis.

With our chosen method, higher IP values indicate richer graves, while lower IP values indicate poorer graves. The summed IPs of the individual graves serve as the basis for determining the normalised Gini index (based on the R code of Marzian 2021) for the individual time stages of the cemetery (Table 2 and Fig. 3). Furthermore, the average wealth and subsistence level are determined on the basis of the IPs (Table 2). Finally, the MFI and IER are calculated with the information on Gini indices, average wealth and subsistence minimum (see formulas above). The MFI therefore is calculated as a MFG.

Main archaeological (burial) group	Specific archaeological groups	Chronological phases	cal BCE (Görsdorf 2000)
Ludanice group	Ludanice group (Lengyel culture)	Eneolithic graves and settlement	4300-4200
I – Nitra culture	Proto and Early Nitra culture Classical Nitra culture	Jelšovce I/II	2030-1850
II – Únětice culture	Early Únětice culture (Late Nitra culture) Classical Únětice culture	Jelšovce III/IV	1850-1730
III – Mad'arovce culture	Early Mad'arovce culture Classical Mad'arovce culture Late Mad'arovce culture	Jelšovce V, VI, VII	1730-1530

Table 1. Chronology and archaeological groups of the site of Jelšovce (Slovakia). The analysis follows the main archaeological groups of the Slovakian Bronze Age.

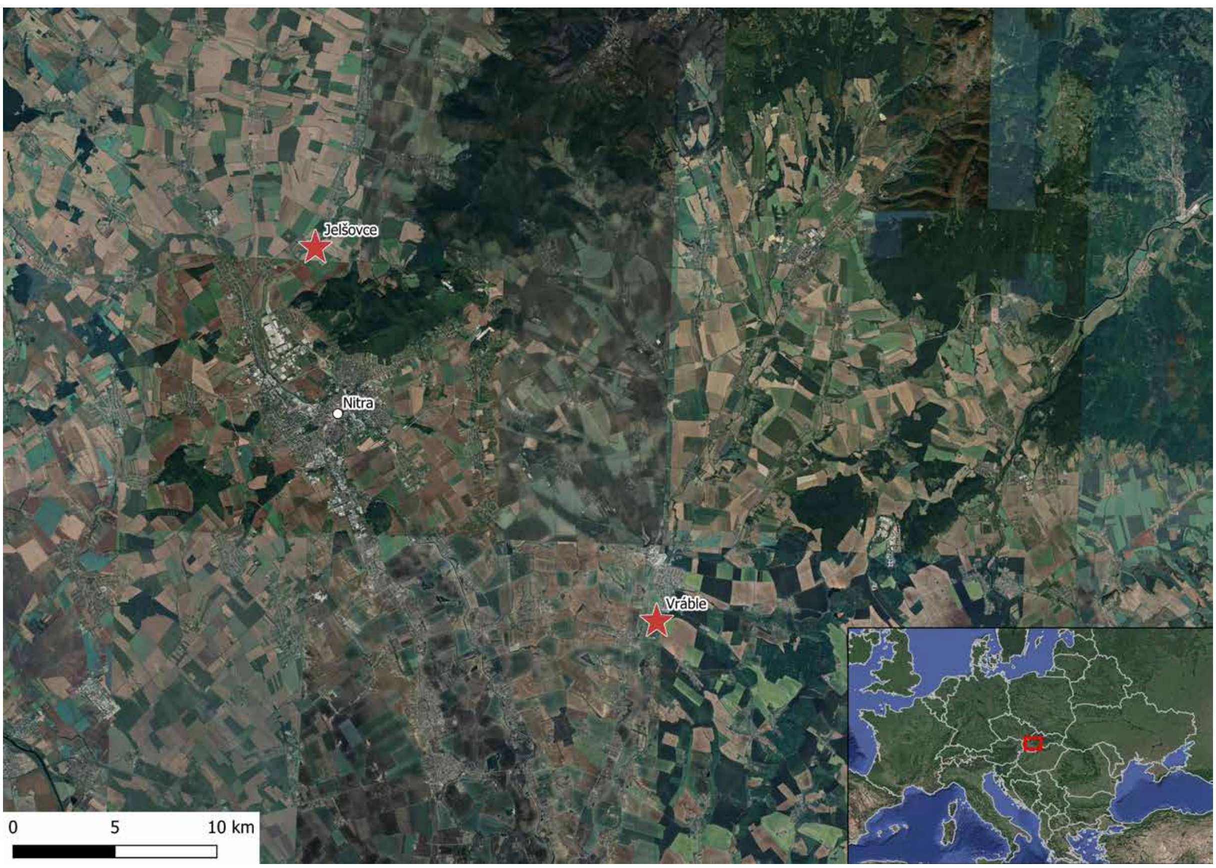

Figure 2. Southwest Slovakia and the location of the Early Bronze Age cemetery of Jelšovce and the settlement and cemetery of Vráble (map: Google, ©2022 TerraMetrics).

We would like to point out that our results are only comparable with results obtained using the same index. If a different grave index is used to calculate the Gini index, the IPF or the MFI, such as the mere number of grave goods in a grave, the results will change. When choosing an index, it is therefore important to consider what it measures and whether the index used is related to the phenomenon one wants to measure. In our example, the wealth of a grave is defined by the frequency of a type of grave good in connection with the number of grave goods and the depth of the grave. We thus resort to an index method that has already been used in past studies as an indicator of social and economic differences (Hedeager 1990; Müller 1994; Rebay-Salisbury 2006; Bösel 2008).

The burial site of Jelšovce

The site of Jelšovce was as an ideal case study to test IPF/MFG and IER as an enhancement of, or supplement to, the measured Gini index when interpreting social developments in prehistoric societies. The site's suitability is due to the wide range of interdisciplinary data available: a detailed catalogue and a typological analysis, radiocarbon dates, Sr isotope and anthropological studies (Pavúk and Bátora 1995; Bátora 2000a; Görsdorf 2000; Reiter and Frei 2015). The burial ground was used for the duration of the EBA and is an accurate archive of the socio-economic developments in this period, due to its completeness of the archive and temporal depth

Jelšovce is located in the valley of the River Nitra, in south-western Slovakia (Fig. 2), on the north-western edge of the Carpathian Basin. Nearby are several contemporaneous sites, and the region is known for its rich archaeological resources, especially from the EBA. Strung along the River Nitra, Váh, Hron and Žitava are all substantial burial sites, each with up to several hundred graves.

The site was excavated from 1982 to 1987 and published by Jozef Bátora (1995, 2000). In total, 616 graves are known from the EBA, 174 of which belong to the Nitra culture, 120 to the Únětice culture and 310 to the Maďarovce culture. Additionally, 24 buried individuals and building remains of the Ludanice group of the Lengyel culture were uncovered. In his analysis Bátora (2000b, 508) proposes a three-partite spatial and chronological structure following the traditional nomenclature of the EBA archaeological cultures: Nitra (I), Únětice (II) and Maďarovce (III). With the help of typochronological analysis and radiocarbon dating, he identified finer chronological differences within the three groups and developed a seven-stage chronology for the burial ground of Jelšovce. For our analysis, we concentrate on the three major chronological units based on the site plan (Bátora 2000b, Fig. 688), as these units provide robust sample sizes (Table 1).

Settlement dynamics and violence in the Early Bronze Age

For the interpretation of inequality measurements, it is crucial to discuss the results in light of other, contemporary social developments. The EBA in the Carpathian Basin was a period of socio-economic and cultural changes. These changes are visible in settlement structure, burial rites and material culture (*e.g.* Earle and Kolb 2010). Well-preserved archives, new methods, and interdisciplinary research are the key to perceive this development in the archaeological record. Multidisciplinary research spanning the past 20 years in the neighbouring Žitava Valley (Skorna *et al.* 2018; Furholt *et al.* 2020; Müller-Scheeßel *et al.* 2020) provides clear comparative data for the EBA.

The extensive archaeological surveys and excavations focusing on the settlement structure showed that a centralisation process took place over the course of the EBA (Müller-Scheeßel *et al.* 2020). The beginning of the period displays a dispersed settlement pattern, with smaller, fortified settlements at around 2100/2050 BCE. This picture changed drastically around 1950 BCE, when the former smaller site at Vráble started to grow rapidly, from an original estimated population of 150-288 to 600-1000 inhabitants. At the same time the smaller settlement sites in the river valley are abandoned and the population of their social groups most likely moved to this new central place at Vráble around the middle of the EBA (Skorna *et al.* 2018; Müller-Scheeßel *et al.* 2020). Around 1730 BC, a catastrophic fire destroyed most of the settlement, after which a drastically reduced population of ca. 150-280 inhabitants rebuilt the settlement inside a substantial earthwork

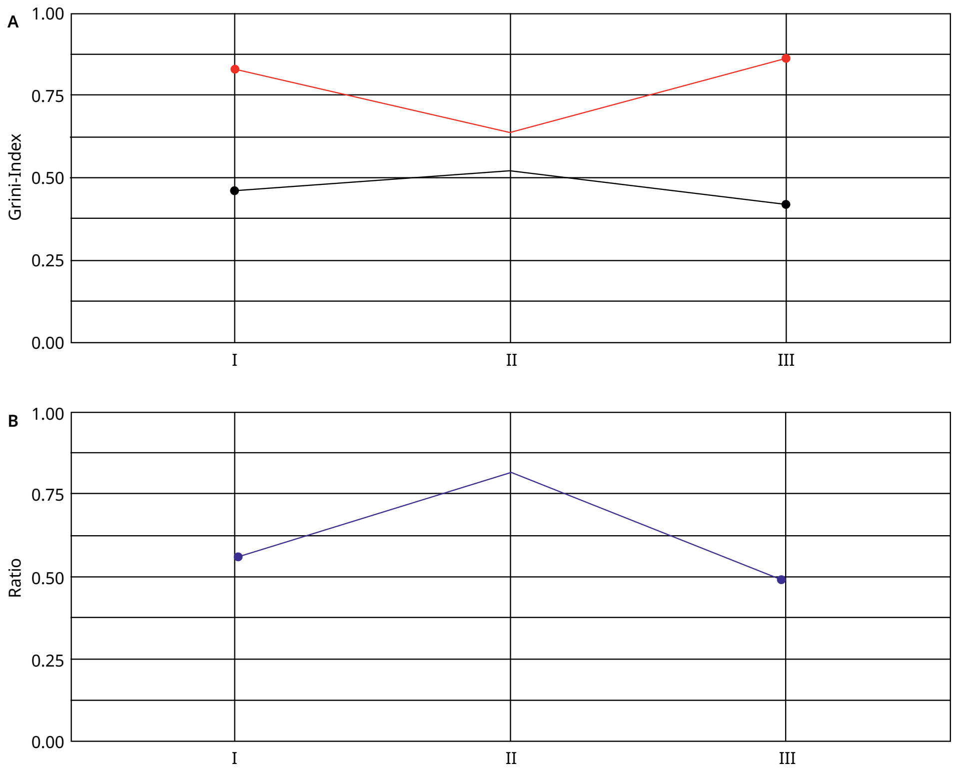

Figure 3. Results of the measured Gini index (A, black); Maximum Feasible Gini Index (A, red); and Inequality Extraction Ratio (B, blue) analyses at the site of Jelšovce. Roman numerals indicate the single burial groups or burial phases, as shown in Table 1.

Groups	Subsistence minimum (IP)	Mean wealth (IP)	α	Gini index	Maximum Feasible Gini Index	Inequality Extraction Ratio
Nitra culture (n=94)	1.24	7.21	5.8	0.46	0.83	0.56
Únětice culture (n=46)	2.08	5.72	2.8	0.52	0.64	0.82
Maďarovce culture (n=147)	0.93	6.62	7.1	0.42	0.86	0.49

Table 2. Results of the Gini index, Maximum Feasible Gini Index and Inequality Extraction Ratio analyses at the site of Jelšovce. Subsistence minimum and mean wealth are given in index points. IP – Index points, α – ratio of average wealth to subsistence minimum, n – number of undisturbed burials that have been included in the analysis.

fortification. At the same time, the settlement pattern reverted to being dispersed. This likely indicates that the end of the EBA, the social groups formerly located at Vráble moved away and resettled in smaller groups.

While external factors cannot be ruled out for the destruction of this central place, tensions between the social groups at Vráble are the most plausible explanation for its collapse (Skorna *et al.* 2018). The deliberate and precise desecration of graves at the burial ground belonging to the site indicate actors with local knowledge (Müller-Scheeßel *et al.* 2020), which supports the supposition of internal conflict. Furthermore, the high incidence of trauma at the skeletal material from Vráble (Stucky 2018), as well as from the burial grounds of Mýtna Nová Ves (Scheelen-Nováček *et al.* 2020) and Jelšovce (Koel 2011, 319), hints at the potential of conflict and to more violence-prone conflict resolution strategies during this time.

This process of agglomeration of population at one site followed by a decline indicated by a dispersed settlement pattern is known to be a common occurrence in the Carpathian Basin at the end of the EBA (Bátora *et al.* 2012, 125). It is very likely that the developments in the settlement system outlined above had a social-economic impact that should be visible archaeologically as the development of wealth inequality.

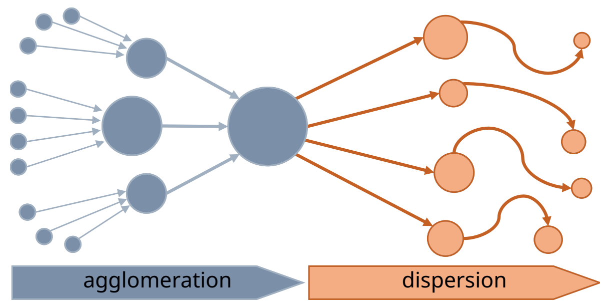

Figure 4. Schematic of the agglomeration and dispersion process as described by Müller-Scheeßel et al. (2020, Fig. 6).

Combining the archaeological record, the Inequality Possibility Frontier and the Inequality Extraction Ratio

The results of the analysis of the individual cemetery areas show that the measured Gini indices are on a moderate level, between 0.42 and 0.52 (Table 2, Fig. 3). The measured Gini index in the three successive EBA burial groups increases from the Nitra (0.46) to the Únětice culture (0.52) and drops in the Mad'arovce culture (0.42). The MFG in the grave groups of the Nitra (0.83) and Mad'arovce (0.87) cultures is higher than the MFG of the graves of the Únětice culture (0.64). The IER is highest in the grave group of the Únětice culture (0.82). The grave groups of the Nitra (0.56) and Mad'arovce (0.49) cultures show a relatively moderate level of exploitation.

In the case of the successive grave groups of the Nitra, Únětice and Mad'arovce cultures, we assume a large regional population due to these groups' sizes. The moderate change in the measured Gini index contrasts with the pronounced chronological differences in the MFG. There is a clear drop in MFGs towards the Únětice culture, which is preceded and followed by high MFGs in the Nitra and Mad'arovce cultures. The substantial IER of the Únětice indicates that 82% of the surplus was extracted. We assess this resulting high IER in the Únětice culture as an indicator of wealth concentration within a small group (the elite). In the Nitra and Mad'arovce groups, the low IERs indicate that there was not such a pronounced extractive process.

We note that the described differences in Gini values between the three archaeological groups represented in the cemetery are rather small and can only be seen as tendencies. However, these results can be linked to the process of agglomeration and dispersal (Müller-Scheeßel *et al.* 2020) in the settlement structure of the region outlined above (Fig. 4). The dispersed settlement landscape at the beginning of the EBA (Nitra culture) goes hand in hand with a low subsistence minimum and a high average wealth. The potential for inequality is not exploited in these smaller settlement networks. We do not discern any excessive extraction of surplus by one group here; rather, surplus remains largely available to society as a whole. With the formation of central sites in the middle EBA, such as at Vráble, in the Žitava Valley, and the associated concentration of the population, is an indicator of a socio-economic upheaval in the Jelšovce cemetery. The burial group of the Únětice culture has a higher subsistence minimum, a lower average wealth and a clear extraction of the surplus – indicated by the high IER.

The reasons for population concentration processes are manifold, including greater efficiency, specialisation and realisation of larger communal projects. An increased need for security may have also played a role (Müller-Scheeßel *et al.* 2020). As determined by anthropological research, the observed increase in interpersonal violence over the course of the EBA at Vráble (Stucky 2018, 97) and Jelšovce (Koel 2011, 319) probably represents an impetus for the agglomeration processes.

In exchange for this heightened security, as exemplified by the fortification at Vráble, a higher subsistence minimum, with lower average wealth, was accepted during the Únětice period. The concentration of the surplus with a limited number of actors in the community, characterised by a high IER, may have also precipitated the dispersal of settlement activity in the Maďarovce period.

The unequal distribution of the surplus, paired with a diminished capacity to produce surplus and raise the mean wealth, likely increased social tension and discontent among the disadvantaged parts of the community. Moreover, the relocation of the population outside the fortifications at Vráble in the course of the middle and late EBA (Bátora *et al.* 2012; Skorna *et al.* 2018) indicates that the threat that had precipitated the need for agglomeration and increased security may have been removed. The internal tensions caused by the agglomeration, exacerbated by the extraction of wealth by one group, may have led to further escalation of tensions. This fractious environment led to the disassociation of the community and heralded the return to a dispersed settlement structure at the end of the middle EBA (Skorna *et al.* 2018; Müller-Scheeßel *et al.* 2020).

Evidence of this internal conflict may be visible at Vráble, where social tensions may have led to violent conflict that resulted in the destructive fire and ultimately led to a collapse of the community (Skorna *et al.* 2018; Müller-Scheeßel *et al.* 2020). The neighbouring community at Jelšovce shows that the subsequent, smaller settlement groups of the Maďarovce culture have a comparatively low measured Gini index in relation to a high MFG. This results in a low IER compared with the previous time period (Únětice culture), indicating a more even distribution of wealth. These groups are economically more effective compared with the Únětice culture, as evidenced by the low subsistence minima and higher average wealth.

In summary, the societies of the Nitra and Maďarovce culture are more economically effective when viewed through the lens of MFG and IER. They settled in a dispersed system and were organised in smaller social groups. Within these groups, a moderate inequality is recognisable, but the economic surplus is extracted to a lesser extent by only one group.

The observed changes in the settlement structure led to a concentration of several social groups at central places during the Únětice period. This was probably triggered by a greater need for security. Using MFG and IER, it is possible to see that this agglomeration process led to lower economic capability to generate wealth and surplus. However, it appears that a large part of the surplus was extracted by one social group, which likely led to inner conflict and a general dispersal of the Maďarovce culture.

Discussion: A better understanding of inequality

The aim of this paper was to test if IPF, MFG and IER could add further informative value to the Gini index and our understanding of inequality within prehistoric societies. As we have elaborated, using excavated evidence from the Bronze Age cemetery of Jelšovce and its surroundings, IPF, MFI and IER provide helpful and quantifiable benchmarks for social inequality and exploitation.

The Gini index only shows slight variability in social inequality between the three main cultural phases represented in the cemetery. However, through the lens of MFG and IER, the social upheavals of the EBA and the possible social developments are clearly visible. Through the IER, we were able to record the movement of wealth or resources within the society. It shows that during the Únětice culture, a large part of the wealth exceeding the subsistence level was

withdrawn from society as a whole by a limited group. The IER thus provides a tool to look at a possible driver of inequality, namely, the exploitation of surplus caused by single social groups and the economic situation of the societies under consideration. The MFI or MFG are useful tools to compare measured inequality between burial phases (as in our example) or even between prehistoric and modern datasets, and to consider potential inequality within societies.

In this paper, we have given an example of how it is possible to apply the concept of IPF and IER of Milanovic, Lindert and Williamson to prehistoric burial data. We are aware of the problems that still exist to establish the IPF and MFI as a standardised method in archaeology. Among the most pressing problems are certainly the question of a generalised burial index, a universal subsistence minimum and a uniform methodology to ensure the comparability of results between datasets. However, we believe that further work on the implementation of the methods presented here on archaeological datasets is worthwhile and will add value to the fields of economic and social archaeology. It is important to acknowledge that the analysis presented here serves purely as a model intended to stimulate a discussion on the implementation and further development of IPF and IER in archaeology.

Acknowledgements

We dedicate this paper to Johannes Bröcker, who inspired us to implement the IPF in the archaeology methodological toolbox. Sadly, Johannes Bröcker passed away before we could move forward on this idea together.

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References

Ames, K.M. and Grier, C., 2020. Inequality on the Pacific Northwest Coast of North America measured by house-floor area and storage capacity. *Antiquity*, 94 (376), 1042-1059.

Arponen, V.P.J., Müller, J., Hofmann, R., Furholt, M., Ribeiro, A., Horn, C., Hinz, M., 2016. Using the capability approach to conceptualise inequality in archaeology: the case of the Late Neolithic Bosnian site Okolište c. 5200-4600 bce. *Journal of Archaeological Method and Theory*, 23 (2), 541-560.

Basri, P. and Lawrence, D., 2020. Wealth inequality in the Ancient Near East: a preliminary assessment using Gini coefficients and household size. *Cambridge Archaeological Journal*, 30 (4), 689-704.

Bátora, J., 2000a. *Das Gräberfeld von Jelšovce/Slowakei. Ein Beitrag zur Frühbronzezeit im nordwestlichen Karpatenbecken. Teil 1*. Kiel: Oetker-Voges Verlag.

Bátora, J., ed., 2000b. *Das Gräberfeld von Jelšovce/Slowakei. Ein Beitrag zur Frühbronzezeit im nordwestlichen Karpatenbecken. Teil 2*. Kiel: Oetker-Voges Verlag.

Bátora, J. Behrens, A., Gresky, J., Ivanova, M., Rassmann, K., Tóth, P. Winkelmann, K., 2012. The rise and decline of the Early Bronze Age settlement Fidvár near Vráble, Slovakia. *In:* J. Kneisel, ed. *Collapse or continuity? Environment and development of Bronze Age human landscapes: Proceedings of the international workshop*

'Socio-environmental Dynamics over the Last 12000 Years': the Creation of Landscapes II. Bonn: Dr. Rudolf Habelt GmbH, 111-129.

Beyer, A., 2020. *Soziale Diversität in Mittel- und Nordeuropa während der älteren Römischen Kaiserzeit – eine statistische und sozialarchäologische Analyse*. PhD dissertation, Freie Universität Berlin. DOI: 10.17169/refubium-28522

Bösel, M., 2008. Wandel durch Bronze? Vergleichende Untersuchung sozialer Strukturen auf früh- und mittelbronzezeitlichen Gräberfeldern im Theißgebiet. *Prähistorische Zeitschrift*, 83 (1), 43.

Earle, T.K. and Kolb, M.J., 2010. Regional settlement pattern. *In:* T.K. Earle and K. Kristiansen, eds. *Organizing Bronze Age societies: the Mediterranean, central Europe, and Scandinavia compared*. Cambridge: Cambridge University Press, 57-121.

Fochesato, M., Bogaard, A., Bowles, S., 2019. Comparing ancient inequalities: the challenges of comparability, bias and precision. *Antiquity*, 93 (370), 853-869.

Furholt, M., Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheeßel, N., eds., 2020. *Archaeology in the* Žitava *Valley I: the LBK and* Želiezovce *settlement site of Vráble*. Leiden: Sidestone Press.

Görsdorf, J., 2000. Interpretation der Datierungsergebnisse von Menschenknochen aus dem Gräberfeld Jelšovce. *In:* J. Bátora, ed. *Das Gräberfeld von Jelšovce/ Slowakei. Ein Beitrag zur Frühbronzezeit im nordwestlichen Karpatenbecken. Teil 2*. Kiel: Oetker-Voges Verlag, 565-570.

Grossmann, R., 2021. *Insights into social inequality: a quantitative study of Neolithic to early medieval societies in southwest Germany*. Leiden: Sidestone Press.

Hedeager, L., 1990. *Danmarks jernalder: Mellem stamme og stat*. PhD dissertation, Aarhus Universitet. Aarhus: Aarhus Universitetsforlag.

Holten, L., 1989. Slangehovedringene i yngre romersk jernalder i Østdanmarken social analyse. *In:* L. Jørgensen, ed. *Simblegård – Trelleborg : danske gravfund fra førromerks jernalder til vikingetid*. Copenhagen: Arkæologisk Institut Universitet, 72-130.

Kerig, T., Bröcker, J., Ohlrau, R., Schreiber, T., Skorna, H., Wilkes, F., 2022. An archaeological perspective on social structure, connectivity and the measurements of social inequality. *In:* J. Müller, ed. *Connectivity matters! Social, environmental and cultural connectivity in past societies*. Leiden: Sidestone Press, 93-114.

Koel, K., 2011. *Paläopathologische und bioarchäologische Untersuchungen an den frühbronzezeitlichen Skeletfunden der Erwachsenenpopulation von Jelšovce (Slowakische Republik). Ein Beitrag zur Rekonstruktion des Gesundheitsstatus frühbronzezeitlicher Populationen*. Unpublished PhD dissertation, University of Hildesheim.

Kohler, T.A., Smith, M. E., Bogaard, A., Feinman, G. M., Peterson, C. E., Betzenhauser, A., Pailes, M., Stone, E. C., Marie Prentiss, A., Dennehy, T. J., Ellyson, L. J., Nicholas, L. M., Faulseit, R. K., Styring, A., Whitlam, J., Fochesato, M., Foor, T. A., Bowles, S., 2017. Greater post-Neolithic wealth disparities in Eurasia than in North America and Mesoamerica. *Nature*, 551 (7682), 619-622.

Marzian, J., 2021. *Measuring wealth inequality in pre-Christian Europe using burial mounds data*. Unpublished master's thesis, Kiel University, Kiel.

Milanovic, B., 2006. An estimate of average income and inequality in Byzantium around year 1000. *Review of Income and Wealth*, 52 (3), 449-470.

Milanovic, B., 2009. Global inequality and the Global Inequality Extraction Ratio: the story of the past two centuries. *Policy Research Working Papers*. World Bank. DOI: 10.1596/1813-9450-5044

Milanovic, B., 2013. The Inequality Possibility Frontier: extensions and new applications. *Policy Research Working Papers*. World Bank. DOI: 10.1596/1813-9450-6449

Milanovic, B., Lindert, P.H., Williamson, J.G., 2011. Pre-industrial inequality. *The Economic Journal*, 121 (551), 255-272.

Milanovic, B., Williamson, J.G., Lindert, P.H., 2007. *Measuring ancient inequality*. Cambridge, MA: National Bureau of Economic Research.

Müller, J., 1994. Zur sozialen Gliederung der Nachbestattungsgemeinschaft vom Magdalenenberg in Villingen. *Prähistorische Zeitschrift*, 69, 175-221.

Müller-Scheeßel, N., Gerbecks, P., Rassmann, K., 2020. Frühbronzezeitliche Befestigungen im oberen Žitavatal. Prozesse von Synoikismos und Dinoikismos. *Slovenská Archeológia*, 68 (Suppl. 1), 417-428.

Pavúk, J. and Bátora, J., 1995. *Siedlung und Gräber der Ludanice-Gruppe in Jelšovce*. Nitra: Archäologisches Institut der Slowakischen Akademie der Wissenschaften.

Porčić, M., 2012. Social complexity and inequality in the Late Neolithic of the central Balkans: reviewing the evidence. *Documenta Praehistorica*, 39, 167-184.

Porčić, M., 2019. Evaluating social complexity and inequality in the Balkans between 6500 and 4200 BC. *Journal of Archaeological Research*, 27 (3), 335-390.

Rebay-Salisbury, K., 2006. *Das hallstattzeitliche Gräberfeld von Statzendorf in Niederösterreich*. Bonn: Dr. Rudolf Habelt GmbH.

Reiter, S. and Frei, K.M., 2015. Migration and identity at the Early Bronze Age cemetery of Jelšovce, southwest Slovakia: the strontium evidence. *In:* P. Suchowska-Ducke, S. Reiter, H. Vandkilde, eds. *Forging identities: the mobility of culture in Bronze Age Europe: report from a Marie Curie project 2009-2012 with concluding conference at Aarhus University, Moesgaard 2012*. Oxford: British Archaeological Reports, 121-130.

Requate, T., 2023. [Lemmata] Measures of Inequality. *In:* T. Kerig, ed. *An ABC of past social inequality* [online]. Available from: https://www.wikis.uni-kiel.de/roots-inequalities/doku.php/wiki/measures_of_inequality

Scheelen-Nováček, K., Nováček, J., Bátora, J., Kierdorf, H., Schultz, M., 2020. Analyse und Interpretation von Schädelverletzungen bei frühbronzezeitlichen Bestattungen vom slowakischen Fundplatz Ludanice-Mýtna Nová Ves. *In:* P. Morgenstern, ed. *Beiträge zur Archäozoologie und Prähistorischen Anthropologie* Band XII. 27th ed. Langenweißbach: Beier und Beran, 13-26.

Siklósi, Zs., 2013. *Traces of social inequality during the Late Neolithic in the eastern Carpathian Basin*. Budapest: Eötvös Loránd University, Institute of Archaeological Sciences.

Skorna, H., Kalmbach. J., Bátora, J., 2018. Vráble, Slowakei. Herausbildung und Niedergang des frühbronzezeitlichen Siedlungszentrums. Untersuchungen zu Wirtschaft, Sozialstruktur und politischer Organisation eines Sozialverbandes und seines Umfeldes. Überblick und die Arbeiten in der Siedlung 2017. *e-Forschungsberichte des DAI*, 1, 101-108. DOI: 10.34780/1lq1-g665

Stucky, K., 2018. Vráble, Slowakei. Die Forschungen auf dem frühbronzezeitlichen Gräberfeld. Die Arbeiten seit 2015. *e-Forschungsberichte des DAI*, 1, 96-100. DOI: 10.34780/d6c6-2q9e

Ubelaker, D.H. and Pap, I., 1996. Health profiles of a Bronze Age population from northeastern Hungary. *Annales Historico Naturales – Musei Nationalis Hungarici*, 88, 271-296.

Wilkes, F. and Skorna, H., 2022. The dawn of the Early Bronze Age in south-western Slovakia – a re-evaluation of the social structure and chronology of Výčapy-Opatovce. *Slovenská Archeológia*, 70 (1), 63-80.

Windler, A., Thiele, R., Müller, J., 2013. Increasing inequality in Chalcolithic southeast Europe: the case of Durankulak. *Journal of Archaeological Science*, 40 (1), 204-210.

World Food Programme. *The WFP Food Basket* [online]. Available from: https://www.wfp.org/wfp-food-basket [Accessed 16 Jun 2022]

Xu, K., 2003. How has the literature on Gini's index evolved in the past 80 years? SSRN *Electronic Journal*, 2 (4), 244.

PART 3.
ENCLOSURES AND COMMUNAL AREAS

Understanding the variability of deposition practices involving human remains in Neolithic settlements of the northern Carpathian Basin: The Neolithic site of Vráble (Nitra district, Slovakia)

Martin Furholt, Ivan Cheben, Alena Bistáková, Zuzana Hukeľová, Maria Wunderlich, Till Kühl, Nils Müller-Scheeßel, Kata Furholt

Abstract

Here we present the burial material from the Neolithic settlement site of Vráble (5250-4950 BCE), in south-western Slovakia, which represents a unique find with peculiar patterns of special treatment of human bodies beside and in the enclosure ditches. We discuss the significance of these finds in the context of Linear Pottery culture burial and deposition practices in central Europe and dispute that warfare can serve as an explanation for the entire variety of finds. We argue that, instead, the archaeological record is compatible with magical practices, and that magic represents a conceptual framework that can help us understand the finds from Vráble specifically as well as the bodies-in-enclosure-ditch phenomenon generally. We argue that such magical practices could be a response to a crisis, directed towards the negotiation of settlement space and community boundaries.

Keywords: *Neolithic in Europe, LBK, enclosure ditches, deposition of human remains, magic*

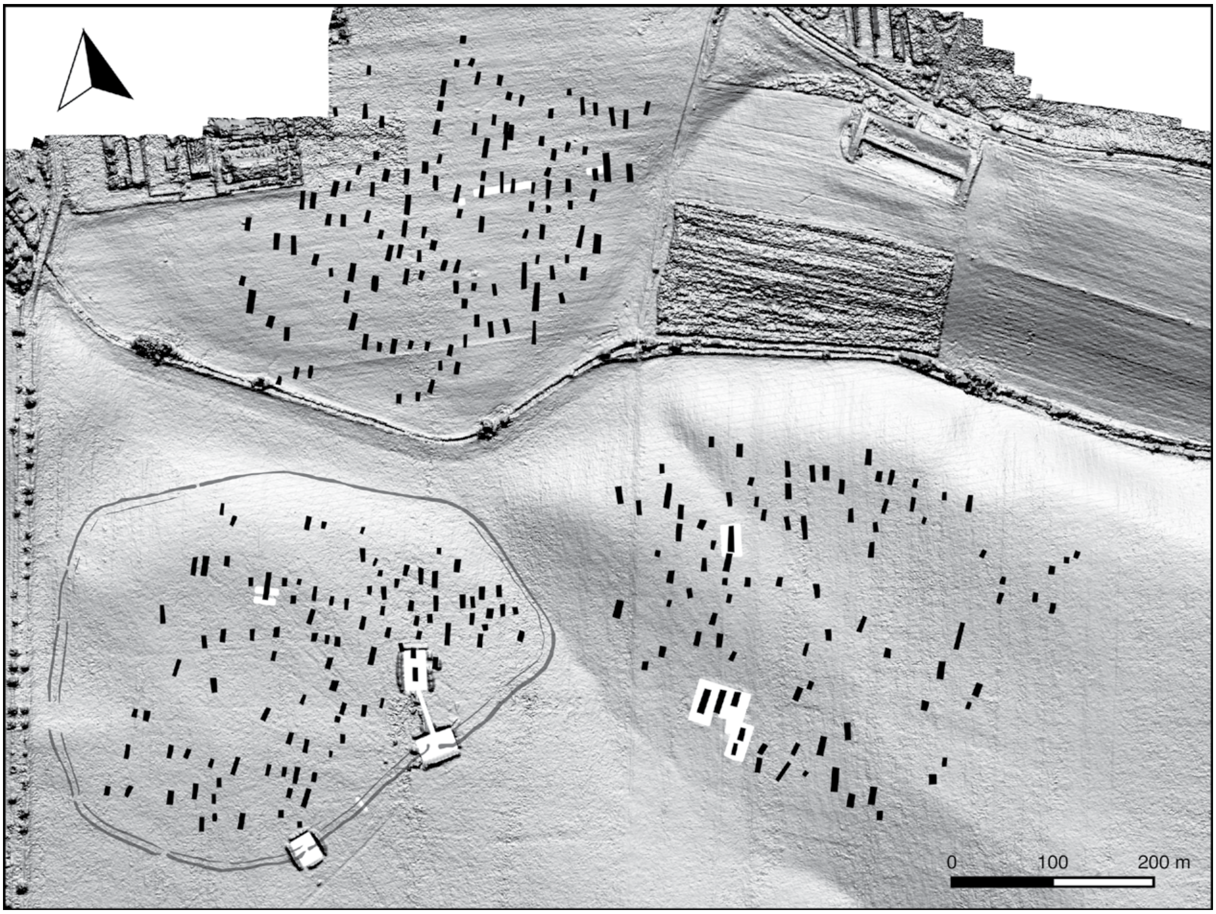

Figure 1. Digital elevation map marked with the location of houses (black rectangles) and enclosure ditches (grey curvilinear lines) in the settlement site of Vráble (Nitra district, Slovakia), as reconstructed from geomagnetic measurements.

Introduction

The Neolithic settlement site of Vráble (5250-4950 BCE), Nitra district, Slovakia, located on the fields named Veľké Lehemby and Farské, is one of the largest Early Neolithic settlement sites in central Europe (Furholt *et al.* 2020a, 2020b). Its extent was determined by geophysical prospection, which shows three spatially separated settlement areas (Pickartz *et al.* 2020; Winkelmann *et al.* 2020) interpreted as neighbourhoods (Furholt *et al.* 2020b), altogether comprising a minimum number of 312 houses (Fig. 1). One of the settlement areas was surrounded by a double enclosure ditch. Fieldwork on the site has been going on since 2010, and during our 2017 campaign, a series of remarkable human burials and partial depositions of bodies were found along the enclosure ditches as well as in their fill, concentrated at two entrance, or gate, areas (Müller-Scheeßel *et al.* 2021). In 2021, we excavated two further gate areas in that enclosure, as well as an area between the gates, and found additional human remains, which provide a fuller understanding of deposition practices at Vráble.

In this paper, we present a preliminary report of the 2021 state of the art concerning our analyses of those findings, as work is still ongoing. We contextualise these new insights into the regional picture of similar depositional practices in other, contemporaneous Linear Pottery culture (German: Linienbandkeramik, LBK) sites and discuss the overall interpretation of this phenomenon in terms of the hypothesis that they relate to warfare, as put forward by Golitko and Keeley (2007) and recently reinforced by Meyer and colleagues (2015, 2018). We argue that the Vráble evidence in context suggests that the explanation of these depositional practices in enclosures

as reflections of warfare between communities is not only insufficiently complex and unrepresentative of the archaeological evidence, but also built on a number of premises that are Eurocentric and unjustified. We therefore propose an alternative reading of the evidence.

The evidence

As was presented and discussed in Müller-Scheeßel *et al.* (2021) and Müller-Scheeßel and Hukeľová (2020), the site of Vráble revealed complex and variable treatments of human bodies, not only within the settlement itself, but also along the enclosure ditches and in their fills. All these activities, including the construction of the enclosure, have been dated to the period 5075-5000 BCE. At the largest entrance, we found a group of burials along the outer ditch (G3, 6-7/S21) and within the inner ditch fill (G9/S21), as well as in one case in the centre of the entrance area (G8/S21) (Fig. 2). These were not so different from 'regular' LBK burials, in that they were deposited in a crouched position, on their side, equipped with pottery, stone tools or animal parts as grave goods (Fig. 3). There are indications at Vráble for practices that deviate from the norm or that have not been observed before. A first group of individuals were not buried immediately, but were probably displayed for a while before they were covered by earth (Müller-Scheeßel *et al.* 2021). A second group were found headless at the bottom of the large outer ditch, namely two pairs of individuals (G4-5/S21; G12-13/S23), stretched out on either their belly or their back. These people's heads were likely carefully removed perimortally, no damages of the upper cervical vertebra were found. (Fig. 4). Another headless individual (G2/S21) was deposited beside the ditch. The skeletal elements of the latter were found in a more irregular position, perhaps as a result of post-depositional processes. A third group were represented by individual bones, skulls, skull parts or limbs found in the fill of both the larger, outer and the smaller, inner ditch (*i.e.* I17/S23). A fourth group consists of two skeletons found in the inner area of the settlement, in, or close by, the typical elongated pits along the house walls, which are usually filled with settlement materials – what archaeologists usually refer to as 'refuse'. While these two skeletons were found in situ, some portions of the bodies had become slightly disarticulated or compressed, indicating some trampling, possibly on the covering earth. A fifth group is represented by a piece of human skull that had been carefully cut, forming a straight edge, and deposited in a refuse pit, together with typical settlement material.

In our excavations in summer 2021, we excavated three new trenches over two entrances into the enclosure and one strip in the middle in order to get more information about the activities farther away from the entrances (Fig. 5). In addition, we re-opened that part of Trench 23 that we had not been able to finish in 2017 – the outer ditch to the east of Entrance 2. We found a confirmation of patterns observed during the 2017 excavations, as well as new patterns. As for the former category, we found individual human limb bones in the fill of the inner ditch as well as the outer ditches close to the entrances (Fig. 6). And we also found two more pairs of headless individuals, which were again deposited at the bottom of the ditch, to the west of the Gates 4 and 3 – that is, in the same manner as with Gates 2 and 1. However, at Gate 3, these headless individuals were found in the inner ditch (Fig. 7) instead of the outer one, and at Gate 4, they were found next to and associated with a third, complete individual (that is, including the head) (Fig. 8).

Finally, a striking new feature was the recurrent combination of human bones and river pebbles in the areas of Gates 3 and 4, something that had not been observed at Gates 1 and 2. These pebbles, varying between 5 and 15 cm in diameter, were found among the individuals' arm and leg bones in the inner ditch

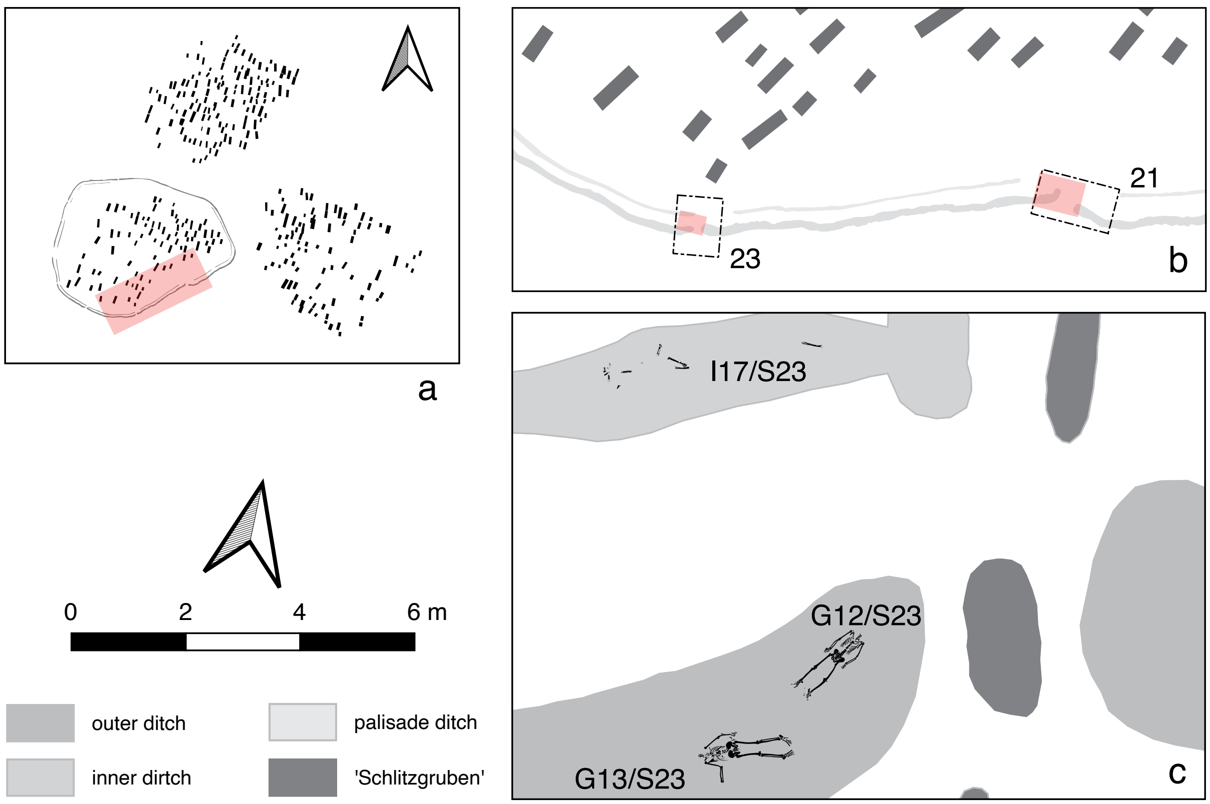

Figure 2A.
The 2017 excavations at Vráble (Nitra district, Slovakia). a: Settlement plan (see Fig. 1) and general location of the trenches with human remains (pink rectangle) (Trench 21, Gate 1, and Trench 23, Gate 2). b: Plan showing the location of Trenches 21 and 23. c: Plan showing the location and anatomical representation of skeletons in Trench 23. Schlitzgruben=deep, narrow pits.

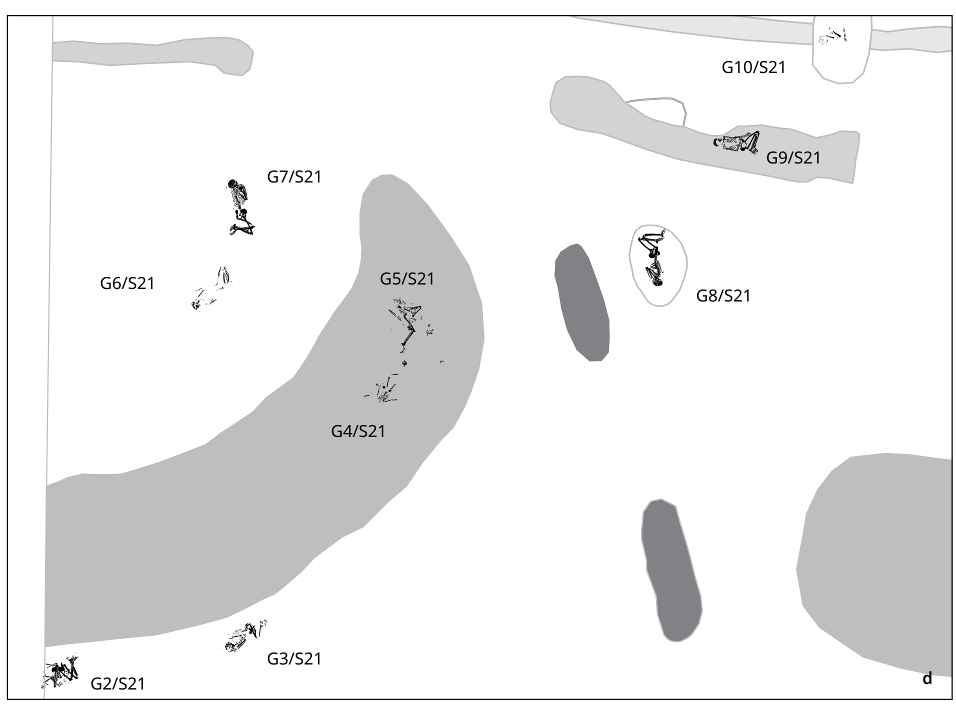

Figure 2B. The 2017 excavations at Vráble (Nitra district, Slovakia). Plan showing the location and anatomical representation of skeletons in Trench 21. Schlitzgruben=deep, narrow pits.

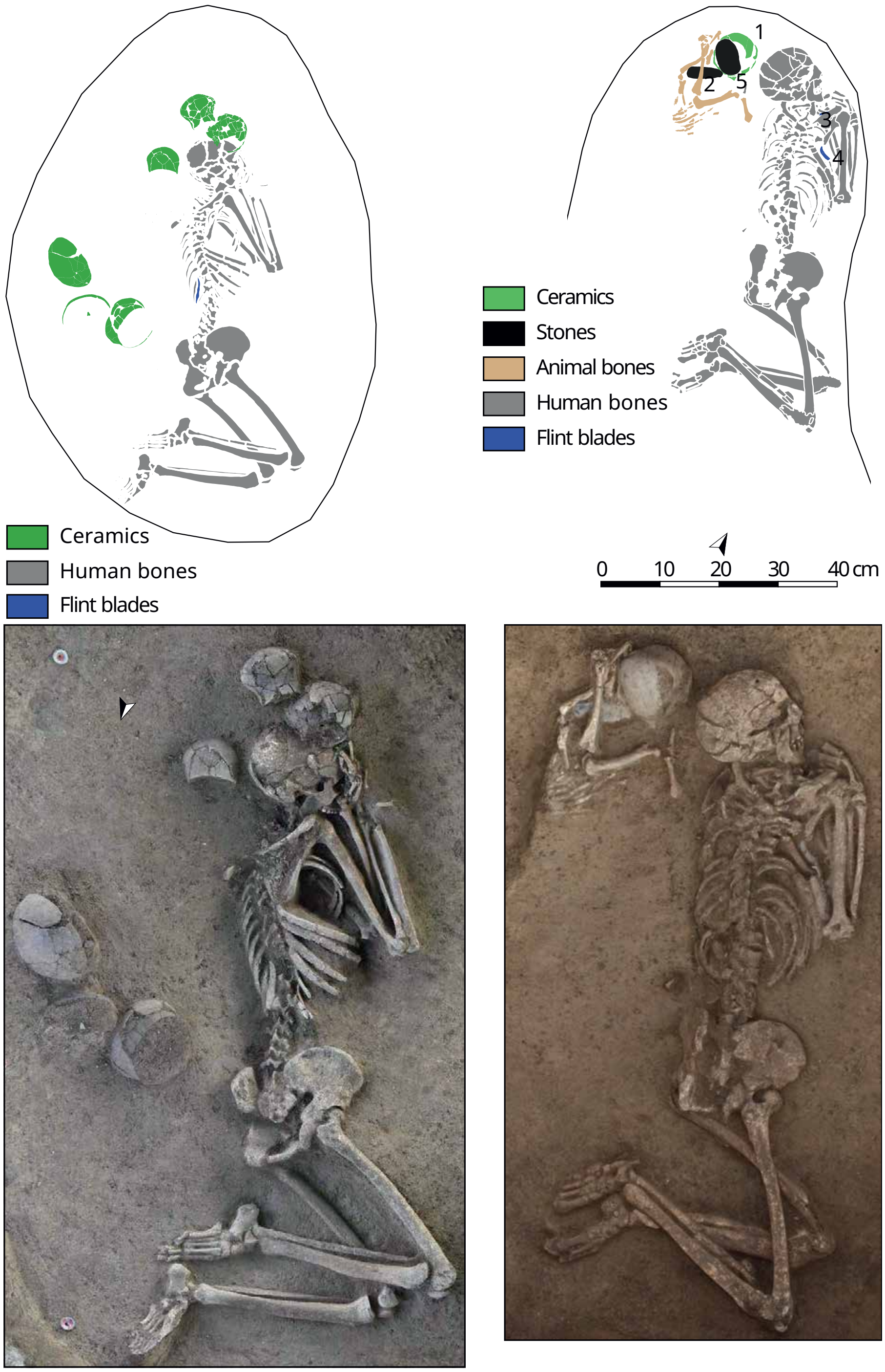

Figure 3. Drawings and photos of two of the 'regular' LBK burials along the enclosure ditches at Vráble (Nitra district, Slovakia) (Trench 21, Gate 1). Image: Nils Müller-Scheeßel.

Figure 4. Photo of one of the pairs of headless individuals on the bottom of the large outer ditch at Vráble (Nitra district, Slovakia) (Trench 23, Gate 2).

close to the entrances, as well as among the pairs of headless individuals. They are of varying raw materials, mostly rounded or slightly rounded. A chert core was also found. The pebbles could derive either from the Pleistocene layers under the site or from creek or riverbeds, the closest of which are the Kováčovsky Potok Creek and the River Žitava. The placement of these pebbles among the human body parts in the ditches is clearly intentional and meaningful, and it is therefore important to note that those pebbles are largely missing at Entrances 1 and 2.

Osteological analyses have not yet been completed on the human bones found in 2021, but analyses on the 2017 materials determined that there were no signs of lethal violence directly causing the death of the individuals, but a lot of minor injuries, such as a healed breaks of the clavicles or hand phalanx – the latter often called boxers' injuries. In one case there is a healed cranial injury which could have been caused by an adze or some similar tool (Müller-Scheeßel *et al.* 2020).

To sum up, our excavations at Vráble show a complex pattern of depositional practices in association with the enclosure ditches, which consist of spatially recurring patterns as well as spatially constrained patterns (Fig. 9). The most striking recurring pattern is the placement of pairs of headless individuals in the ditches to the west of all four entrances so far excavated.

A second recurring pattern is the placement of single human long bones and larger, articulated limb sections all over the ditch near the entrances. It is not yet clear whether these represent the remains of badly preserved complete or headless skeletons. Spatially constricted patterns are the deposition of 'regular', crouched burials with grave goods at the largest entrance, Gate 1, as well as the deposition of pebbles in combination with both individual bones and skeletons at Gates 3 and 4.

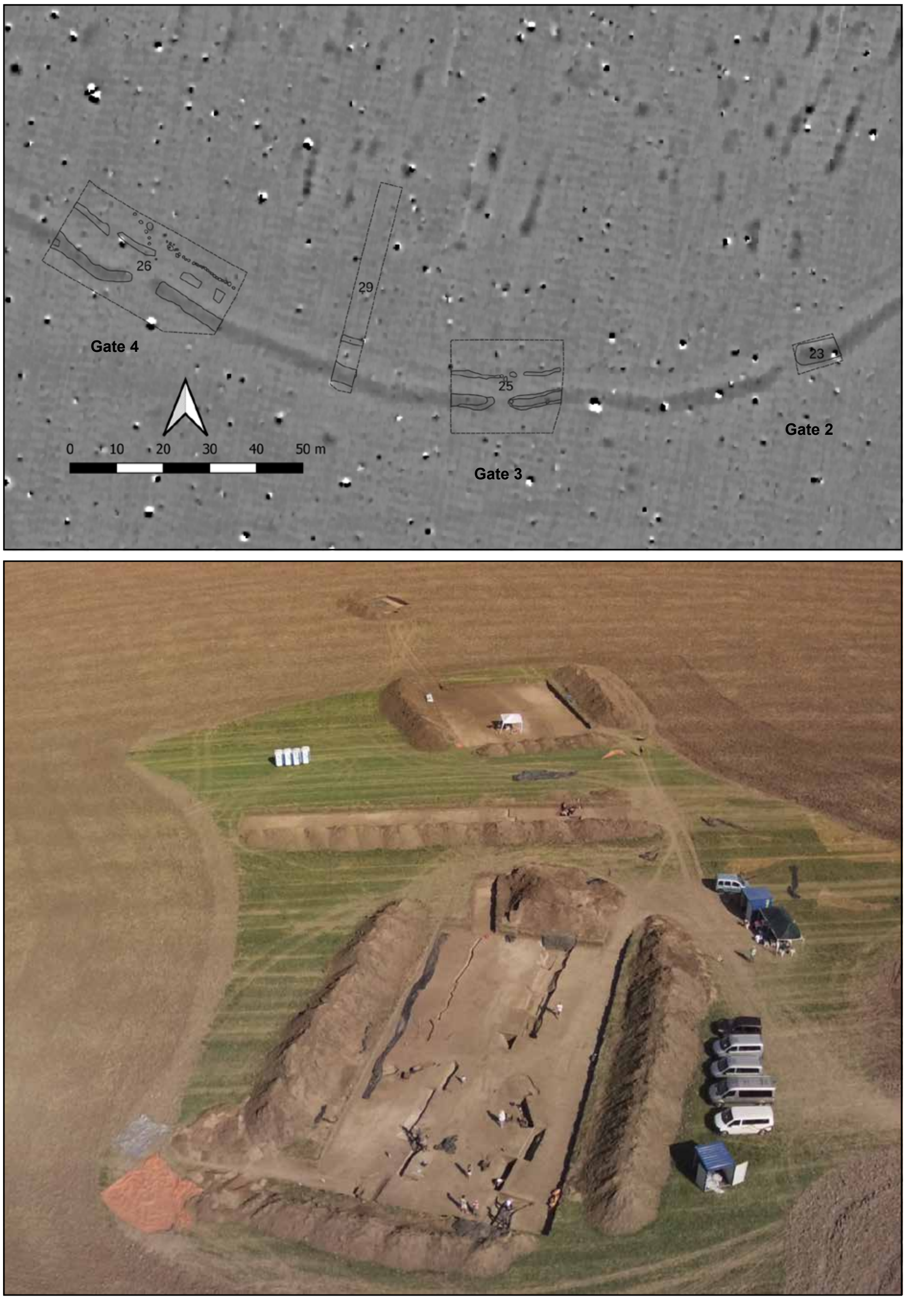

Figure 5. The 2021 excavation at Vráble (Nitra district, Slovakia). Magnetic map showing the location of the excavation trenches; Trench 23 was partly re-opened, as in 2017 it had not been completely excavated (top). Photo of the trenches being excavated (bottom); Trench 26 is closest to the viewer and Trench 23 is farthest away.

There are deviations from the overall patterns such as those seen at Gate 3, where the two headless individuals were not placed in the larger, outer ditch, but in the smaller, inner ditch, and one of the individuals was buried in a crouched position rather than in a stretched-out position, as all the other headless ones at the entrances were. The picture that emerges is of a complex and multilayered set of ritual practices, some following communal standards, others seemingly connected to individual sections of the population.

Figure 6. Photo of isolated human limbs and pebbles in the inner ditch at Vráble (Nitra district, Slovakia) (Trench 26, Gate 4).

The regional context: enclosures and pits with human remains

The phenomenon of human remains in enclosure ditches has been prominently reported from other LBK sites as well (see below) and from contemporary settlement sites in other regions and of other archaeological classifications, such as the Butmir culture site of Okolište, Bosnia (Müller-Scheeßel *et al.* 2009). Some have discussed these practices as being either similar or causally connected, while others propose more varied interpretations for the individual sites. Often, what is reported can be characterised as burials in the enclosure trench, such as the site of Vaihingen an der Enz, in south-western Germany (Krause 1998; Bogaard *et al.* 2016). Here, 80 individuals

Figure 7. Photo of a pair of headless individuals in the inner ditch at Vráble (Nitra district, Slovakia) (Trench 25, Gate 3). The individuals were lying close to each other and were photographed separately.

Figure 8. Photo of a pair of headless individuals and a complete individual in the outer ditch at Vráble (Nitra district, Slovakia) (Trench 26, Gate 4). Image: Till Kühl.

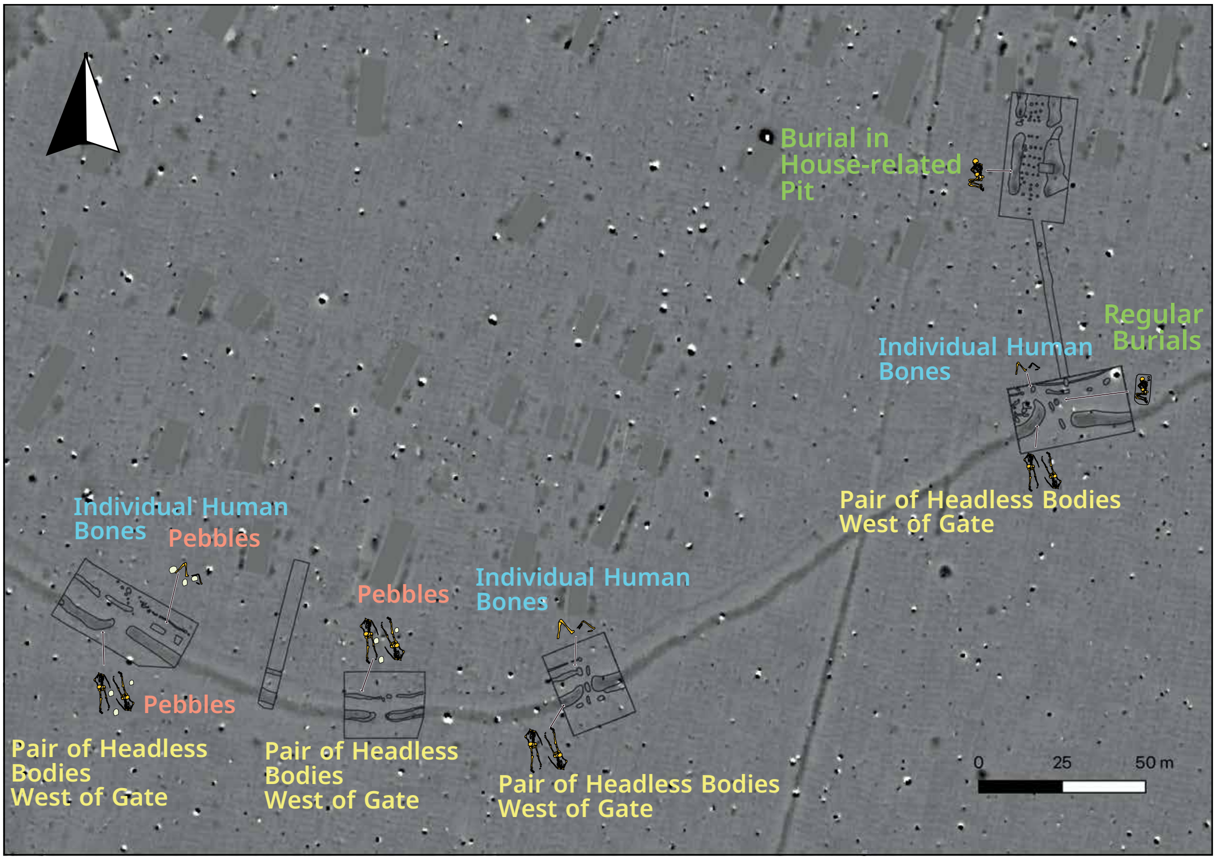

Figure 9. Magnetic map showing distribution of human remains at the gates and enclosure ditches at Vráble (Nitra district, Slovakia), colour coded by type of deposition.

were buried in the trench, and another 40 in pits within the settlement, close to the houses. Isotopic evidence indicates that the people buried in the ditch more frequently showed 'non-local' Sr isotope values than did those buried inside the settlement (Bentley *et al.* 2003).[1]

The first, and most prominent, of the sites with parallels to Vráble is Herxheim, in south-western Germany (Zeeb-Lanz 2016, 2019). Here, the remains of more than 500 human individuals were found in a double ditch system surrounding a settlement that is very much contemporaneous with Vráble – starting around 5300 BCE, while the enclosure is being constructed and the human remains being deposited within a short timespan around 5050 BCE (Riedhammer 2019). The human bones were interred in a highly fragmented way, together with equally fragmented animal bones, crushed pottery and broken stone implements. Importantly however, the dead deposited in the Herxheim ditch do not seem to represent the Herxheim population, as their Sr values indicate people from outside the loess areas typical for LBK settlements, probably the middle mountain ranges in the region (Turck 2019). The human bodies were probably cut up in a rather standardised procedure, post-mortem, which involved a chopping off of extremities, scalping and defleshing. Special attention was given to the skulls, and several heaps of skull calottes were found in the ditch fills. Signs of violence were observed and the presence of a higher percentage of young adults than are found in usual cemetery populations is taken as an indication for 'ritual killings' (Zeeb-Lanz 2019). The idea of cannibalism was postulated by some Herxheim team members (Boulestin *et al.* 2009, 2015)

1 The use of the enclosure ditch at Vaihingen is dated a little earlier than that at Vráble, namely, 5300-5150 BCE (Bentley *et al.* 2003). This dating is, however, based on pottery typological phasing only.

and contested by others (Orschied *et al.* 2012). There are still unresolved debates between the different members of the Herxheim research team (Hofmann 2015): Are we dealing with a massacre or with mainly ritual activities? In our view, this debate revolves around modern terms and concepts, as ritual practices may very well be violent, while massacres may very well include ritual elements.

A second site with similarities to Vráble is in Menneville, in the Aisne Valley, France, where human skeletons and skeletal parts were deposited in the (clearly segmented) enclosure ditches, in combination with animal skeletons and individual bones. Some of the skeletons were missing body parts, which indicates complex patterns of treatment (Hachem 1996).

A third site with similarities is Asparn-Schletz, in Lower Austria, just about 150 km to the west of Vráble (Teschler-Nicola 2012). Here, a minimum of 67 individuals were found, disarticulated, in the outer of two parallel enclosure trenches surrounding the site. This site follows the same chronological pattern as Vráble and Herxheim: The settlement starts around or after 5300 BCE (Windl 1994) and ends around 5000 BC, and the date of the deposition of human bodies is calculated to be somewhere between 5075 and 5000 BC (Riedhammer 2019). The human remains were found in a decidedly disarticulated manner, with a lot of traces of animal gnawing, which indicates that these bones were lying uncovered for a considerable amount of time. All 33 skulls or skull fragments found showed signs of peri-mortem trauma. All age classes are present in the demographic profile, but there is a slight, statistically insignificant underrepresentation of adult females. Teschler-Nicola (2012) concludes, in a graphic and compelling manner, that the evidence points towards a massacre of most of the village population by a group of outside aggressors, who abducted some of the women and threw the deceased in the ditch, constituting a violent end to the settlement.

Such a violent scenario is also proposed regarding the evidence from Talheim, south-western Germany (Wahl *et al.* 1987, 2012; Bentley *et al.* 2008). Here 34 individuals (18 adults and 16 children) were found in a pit within the settlement. As the majority of them showed traces of peri-mortem violence (blows to the head, arrowheads in their back), again a single massacre event is deemed plausible, and despite the fact that the gender ratio between the sexed adult males and females is even, at 9:7 (there are also 2 individuals who could not be sexed), the story of women being abducted is evoked here, too.

Publications of two more recent finds likewise highlight violence in connection with late LBK settlements. At Schöneck-Kilianstedten, central Germany (Meyer *et al.* 2015), central Germany, 26 individuals, 13 adults and 13 subadults, were placed in an elongated pit within the settlement. The majority of the adults were young, and the majority of the children were less than 6 years old. Most of the skulls showed peri-mortem signs of potentially lethal violence, and in addition, the authors argue, there was a systematic breaking of people's lower legs, as a kind of mutilation or torture. At Halberstadt-Sonntagsfeld, central Germany (Meyer *et al.* 2018), nine individuals were found in a settlement pit. Of these, seven were male and two could not definitively be sexed, and they were all adults. In two cases, the skull was missing, but the other seven all showed at least one peri-mortem trauma indicating blunt force. Some showed traces of several blows to the head. Because of the regular pattern, concentrated at the back of people's heads, the authors suggest a mass execution. The dating, most likely between 5080 and 5000 BCE, corresponds will with that of the individuals at Vráble.

At Wiederstedt, central Germany, 10 individuals were found in a typical round settlement pit, 3 of whom were missing their heads (Meyer *et al.* 2004). None of these individuals showed any direct signs of peri-mortem violence. Yet a peculiarity of Wiederstedt is the predominance of children in the pit (8, as

opposed to only 2 adults, namely 1 male and 1 female). This recalls the evidence from the cave known as the Jungfernhöhle, near Tiefenellern, in southern Germany, where children represented 63% of the 41 individuals found, and the great majority of the adults were women. However, recent excavations of the cave by Timo Seregély (2012) cast some doubt on the dating of the entire assemblage to the LBK period.

Human depositions in LBK contexts, and the concept of Magic

The sites discussed above show remarkable variability in the ways of treating human bodies in LBK settlement contexts. At some sites – Schletz, Talheim, Schöneck and Halberstadt – people had clearly been subjected to interpersonal violence, and an interpretation of inter-group warfare is plausible (Golitko *et al.* 2007). At other sites, interpersonal violence is much less prominent (Herxheim, Wiederstedt, Menneville, Vaihingen and Vráble). If we focus just on the sites with evidence of human bodies from enclosure ditches – Herxheim, Vaihingen, Vráble, Menneville and Schletz – we see that the massacre component is much less prominent, with only Schletz being a clear example. However, in Schletz, recent aDNA analyses cast serious doubt on the idea that the group of deceased represent a village population (Gelabert *et al.* 2023). This makes this seemingly clear case of a massacre much less convincing. Taking all these cases together, we see that the post-mortem treatment of bodies is explicitly elaborate and varied.

It is not our intention to downplay the existence of interpersonal violence in the late phase of the LBK. Rather, it is to point out that the phenomenon we are dealing with seems to be a much broader and more complex one, which cannot be explained by warfare alone.

If we look at Early Neolithic LBK communities more broadly (Bickle and Whittle 2013), there are a set of practices that can, in a rather straightforward way, be classified as funerary rituals, even if there is quite a lot of variability here, too. These practices involve the deposition of mostly complete bodies in simple pits, usually in a crouched position on the left or right side, equipped with burial goods in the form of a single or a small number of vessels, tools or ornaments (Nieszery 1995; Hofmann *et al.* 2012). These inhumations can occur in extramural cemeteries, within the settlement, and along or within pits or enclosure ditches (Bickle and Whittle 2013). For these mostly complete bodies, it can be reasonably inferred that we are dealing with some kind of *rite de passage*, with the purpose of transitioning the dead, or parts of their persona, from the realm of the living to a new realm (or location). At Vráble, burials that are the remains of such funerary practices were found along the enclosure ditch, close to the first (main) entrance (Müller-Scheeßel *et al.* 2021), and we distinguish such burials from the partial and headless bodies, whose deposition more likely was connected to magical practices. In those magical practices the human body parts are no longer treated primarily as persons, but basically as a substance, or force, that will have an effect on other substances or forces.

Magic is a global phenomenon that also seems to transcend history (Sørensen 2006; Gosden 2020). It has been widely studied anthropologically – along a spectrum ranging from rather chauvinistic condescension, as superstitious beliefs (Frazer 2002), to acknowledgement of magic as a globally widespread set of specific assumptions about reality, and practices derived from such an ontology (Tambiah 1990; Sørensen 2006). Magic is usually defined as practices carried out on the basis of the idea that entities of the world can be affected or manipulated either by virtue of their similarity with another entity or through contact, as a form of contagion (or transference of forces). Manipulating one entity can have a

direct effect on another (similar) entity far away; alternatively, direct contact with a forceful object can transmit such force (Mauss 2001; Sørensen 2006). Yet how this is done in different cultural contexts varies. Importantly, magic is instrumental, practical and goal-directed, and it can be set in motion by an individual actor, often in secret or concealed, and in this respect magic can be seen as a kind of conceptual opposition to religion, which is usually public, collective, symbolic and repetitive (Hofmann 2020, 136). Magic is materialist and holistic in the sense that it builds upon a cosmology of wholeness of the world, or connectedness of substances and forces (Hofmann 2020, 136) and also gives the individual actor direct power, while religions usually work via the appeal to super-natural powers, such as spirits or gods (Hofmann 2020, 136). Although it is tempting to see religion as being more compatible with stratified societies, even state societies, where untouchable overlords are part of lived realities, in reality, magic and religion coexist and are often intertwined in most societies, and as Mauss (2001) has already pointed out, the opposition between the two is not as clear-cut as anthropologists often would have it be.

Nevertheless, as Hofmann (2020, 135) points out, one can tentatively assume that magical practices will empirically show 'a general indeterminancy and lack of strict coherence', which puts them somewhat in opposition with what are usually referred to as ritual practices. This does, arguably, make them hard to identify archaeologically with certainty. But with a phenomenon such as the practices with human bodies and body parts connected to late LBK ditches and pits in mind, one might reverse the logic and argue that magic actually provides a frame of reference that can include this variability and individual particularity that is visible within an overall structural pattern (*i.e.* dead human bodies in ditches surrounding settlement space).

It is remarkable that we have an entire series of late LBK sites where, in a rather constrained time window of 5100 to 5000 BCE, or even 5080 to 5050 BCE, human bodies and body parts are being deposited in different ways in enclosure ditches surrounding larger villages, and that, at the same time, we also have a clustering of sites where human bodies are deposited in round or elongated settlement pits in different places. The manipulation of bodies is decidedly varied, with different patterns in all of the sites mentioned. In some of these, such as Vaihingen an der Enz, Herxheim and Vráble, meaningful patterns in the treatment and deposition of human bodies seem to be the decisive factor governing the practices observed. At Vaihingen, we talk about regular funerary burials, and these do not actually date to the timespan we are talking about here. At Herxheim and Vráble, the patterns found are individual; they do not reflect a recurring pattern of funerary burials. At Herxheim, the dismemberment and fragmentation of human bodies correspond with chopped-up and fragmented animals and objects, such as pots and stone tools. At Vráble, in some contexts, individual human long bones and body parts, as well as headless individuals, are associated with river pebbles.

What these latter two sites show is that there are concrete underlying meanings at play, but that they differ from site to site, and actually also within different parts of the same site. This is, we would argue, the context within which the evidence from Schletz and Kilianstätten has to be understood. We can call the actions evidenced at the site violent conflict or war, but we see the overall cosmological setting, the conceptual framework within which they take place, as a different than the framework applied by Golitko and Keeley (2007). Warfare between hunter-gatherers and LBK farmers in the early phase and warfare among LBK communities in the later, caused, according to Golitko and Keeley (2007, 339), by '… revenge for prior attacks, land disputes, poaching, prestige, capture of slaves or capture of women'; according to Meyer *et al.* (2015, 11221) by '… a significant increase in population followed by adverse climatic conditions (drought)'; and according to Meyer *et al.* (2018, 7) by 'Climate-induced drops in agricultural land and increasing hierarchical differentiation…'.

Although these papers are cautiously worded, they clearly share the underlying premise of Neolithic communities being distinct social units engaged in an ongoing inter-group competitive race for potentially scarce resources. The premise is based on an imposition of a modernist rationality and, in the case of encounters between Mesolithic hunter-gatherers and Neolithic farmers, a settler colonial mindset, which is being projected onto prehistoric actors. Such a worldview is, however, historically specific (Moore 2016) and builds upon several ontological premises that are not very likely to have governed thinking during the Neolithic. The connection of pebbles and body parts in some sections of the Vráble ditch could, in addition, be seen as an expression of the contagious effects of physical contact of entities in magical practices. The correspondence of chopped-up human bodies, animals and objects of clay and stone at Herxheim points towards some kind of interior similarity or interior connection between physically dissimilar objects, as can be found, respectively, in animistic or analogistic thinking, according to the scheme of Descola (2014, Fig. 2; see also the critical discussion by Fowler 2021). The practices we observe are clearly non-random, meaningful, but still rather site-specifically diverse or even individually distinct. If we assume that magic lies at the basis of the practices discussed here, it becomes possible to read the main theme uniting the otherwise seemingly diverse cases: The combination of dead bodies and the enclosures around village spaces indicates that those practices are aimed at negotiating the tension between individuals, community and their spatial reach. This can have to do with a blocking off aimed at the outside world – what we would conventionally call 'fortification' – or directed towards or against some segments of the community. The latter seems to be the case at Vráble, where the enclosure ditches and the position of the entrances give important clues towards their purpose. The enclosure surrounds only one, the south-western, of the three neighbourhoods of the settlement site. In the fifty-first century BCE, when it was constructed, the two other neighbourhoods were still thriving; indeed the northern one had attracted the highest number of farms, whereas the south-western one was in decline (Müller *et al.* 2020). In this situation, a 1.3 km long double ditch system, at some places also accompanied by a palisade, was erected, significantly blocking access to the two other neighbourhoods. This is especially obvious because all six of the entrances face away from the two other neighbourhoods, and there are no gates towards them. This means that the practical distance between the neighbourhoods was extended by several hundreds of metres. One of the entrances closest to another neighbourhood is the main entrance, in the south-east. But even here, it is striking to see that the enclosure actually curves towards the north-west, so as to intentionally have the gate face away from that other neighbourhood to the east (Fig. 2.a,b). Needless to say, from the perspective of fortification, to have those six entrances facing towards the outside of the settlement, instead of towards the inside, is not very practical. In other words, the Vráble enclosure was clearly not built to fortify the settlement against some outside threat; rather, it was built to separate one section of the site, one neighbourhood, from the others, by creating a physical boundary and interring magical powers drawn from sources that are more difficult for us to understand.

Yet it seems possible to argue, in the case of Vráble, that the enclosure and the depositions had to do with negotiations and conflicts within the residential group of that site. As discussed elsewhere (Furholt *et al.* 2020b; Wunderlich *et al.* 2020), conflicts existed within the Vráble community on several levels: first, between individual farmsteads, which seem to have had a marked autonomy in spite of the village structures they were part of and, second, among the three neighbourhoods (which constituted an intermediate-scale social identity), which may have gradually turned into antagonism between those groups. When seen in its regional context, Vráble is a peculiar mixture between Balkanic villages (Chapman 1989; Furholt 2016) and north European individual farmsteads. As is

the case for western LBK communities, contemporaneous houses are located at quite a distance from each other (80-100 m on average) and seem to constitute individual farms, with their own pottery production and subsistence and with differential access to exotic goods, such as obsidian (Furholt *et al.* 2020b).

This household, or farmstead autonomy exists in combination with the unusual agglomeration of up to 80 contemporaneous farmsteads and the overall layout of the site, which has village-like structures that resemble contemporaneous Vinča tell settlements. So there is something like a combination of strong household autonomy with rather strong village solidarity. Tensions between the interests of the household and those of the village community have been described as an inbuilt feature of Neolithic societies (Leppard 2014, 2021), and at Vráble this would even extend to conflicts between the three scales of social organisation – household, neighbourhood and village community. The enclosure and the magical practices connected to it would then likely be related to attempts to solve or manipulate this tension. The same could be the case for the other LBK sites we discussed here, as they also – being larger agglomerations of independent farmsteads – likely experienced social tensions deriving from the same basic, contradictory social setting.

Conclusion

During the excavation campaigns of 2017 and 2021, we were able to uncover interesting patterns of burial and depositions from the LBK and Želiezovce settlement complex at Vráble-Ve'lké Lehemby. In and along the enclosure ditch we found a striking pattern of recurring, regularly exercised practices, in combination with practices that were unique or restricted to particular entrance areas. In the European context, the elaborate treatment and deposition of human bodies and body parts in and along the enclosure ditch of Vráble is unique in its specific features, but shares overall patterns with several other contemporary LBK settlement sites that also date between 5080 and 5000 BCE. At Vráble, the enclosure is clearly directed inwards, and not constructed to guard from any outside enemy. We interpret all the sites discussed as expressions of magical practices directed towards the manipulation of the complicated relationship between individuality, community and village space, probably relating to the conflicting interests of households, as opposed to of the overall community. To reiterate this point, this does not mean that enclosures at other sites are not to be interpreted as being directed towards the outside, or that sites such as Schletz do not show signs of interpersonal violence or warfare. What it does mean is that, in our view, we would be misrepresenting the material if we were to shoehorn our observations into our modern concept of war and thus ignore the wider context, in which the combination of dead bodies in enclosure ditches and pits show a much more patterned, yet at the same time more variable, structure than would be represented by what is our current understanding of the war-over-scarce-resources model. The model proposed here, that is, a magical negotiation of community and settlement space, includes all kinds of different practices: violent and gruesome ones as well as the more careful post-mortem manipulations seen at Vráble. While we cannot escape the problem that we interpret past societies, people's thoughts and people's intentions starting from our own conceptual toolkit, it is still worth trying to widen the scope of possibilities for interpretation by taking into account as many anthropologically studied phenomena as possible. This can at least help us some of the way to better understanding past people and their societies.

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References

Bentley, R.A., Krause, R., Price, T.D., Kaufmann, B., 2003. Human mobility at the Early Neolithic settlement of Vaihingen, Germany: evidence from strontium isotope analysis. *Archaeometry*, 45, 471-486.

Bentley, R.A., Wahl, J., Price, T.D., Atkinson, T.C., 2008. Isotopic signatures and hereditary traits: snapshot of a Neolithic community in Germany. *Antiquity*, 82, 290-304.

Bickle, P. and Whittle, A.W.R. eds., 2013. *The first farmers of central Europe: diversity in LBK lifeways. Oxford*: Oxbow Books.

Bogaard, A., Arbogast, R.-M., Ebersbach, R., Fraser, R.A., Knipper, C., Krahn, C., Schäfer, M., Styring, A., Krause, R., 2016. *The Bandkeramik settlement of Vaihingen an der Enz, Kreis Ludwigsburg (Baden-Württemberg): an integrated perspective on land use, economy and diet*. Germania : Anzeiger der Römisch-Germanischen Kommission des Deutschen Archäologischen Instituts, 1-60.

Boulestin, B. and Coupey, A.-S., 2015. *Cannibalism in the Linear Pottery culture: the human remains from Herxheim*. Oxford: Archaeopress.

Boulestin, B., Zeeb-Lanz, A., Jeunesse, C., Haack, F., Arbogast, R.-M., Denaire, A., 2009. Mass cannibalism in the Linear Pottery culture at Herxheim (Palatinate, Germany). *Antiquity,* 83 (322), 968-982.

Chapman, J., 1989. The early Balkan village. *Varia Archaeologica Hungarica,* 2, 33-53.

Descola, P., 2014 [2005]. *Beyond nature and culture*. Reprint. Chicago and London: University of Chicago Press.

Fowler, C., 2021. Ontology in Neolithic Britain and Ireland: beyond animism. *Religions,* 12(4), 249.

Frazer, S.J.G., 2002. *The golden bough*. Abridged edition. Mineola, NY: Dover Publications.

Furholt, M., 2016. Settlement layout and social organisation in the earliest European Neolithic. *Antiquity*, 90 (353), 1196-1212.

Furholt, M., Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheeßel, N. (Eds.) 2020a. *Archaeology in the* Žitava *Valley I. The LBK and* Želiezovce *settlement site of Vráble*. Sidestone Press, Leiden.

Furholt, M., Müller-Scheeßel, N., Wunderlich, M., Cheben, I., Müller, J., 2020b. Communality and discord in an Early Neolithic settlement agglomeration: the LBK site of Vráble, southwest Slovakia. *Cambridge Archaeological Journal*, 1-21.

Gelabert, P., Bickle, P., Hofmann, D., Teschler-Nicola, M., Anders, A., Huang, X., Olalde, I., Fournier, R., Ringbauer, H., Akbari, A., Cheronet, O., Lazaridis, I., Broomand-khoshbacht, N., Fernandes, D.M., Buttinger, K., Callan, K., Candilio, F., Bravo, G., Curtis, E., Ferry, M., Keating, D., Freilich, S., Kearns, A., Harney, É., Lawson, A.M., Mandl, K., Michel, M., Oberreiter, V., Oppenheimer, J., Sawyer, S., Schattke, C., Özdoğan, K.T., Hämmerle, M., Qiu, L., Workman, N., Zalzala, F., Mallick, S., Mah, M., Micco, A., Pieler, F., Pavúk, J., Lazăr, C., Paluch, T., Škrivanko, M.K., Šlaus, M., Bedić, Ž., Novotny, F., Szabó, L.D., Cserpák-Laczi, O., Hága, T., Hajdú, Zs., Mirea, P., Nagy, E.Gy., Virág, Zs. M., Horváth, A.M., Horváth, L.A., Biró T., K., Dombóróczki, L., Szeniczey, T., Jakucs, J., Szelekovszky, M., Zoltán, F., Sztáncsuj, S., Tóth, K.,

Csengeri, P., Pap, I., Patay, R., Putica, A., Vasov, B., Havasi, B., Sebők, K., Raczky, P., Lovász, G., Tvrdý, Z., Rohland, N., Novak, M., Ruttkay, M., Borić, D., Dani, J., Kuhlwilm, M., Palamara, P.F., Hajdu, T., Pinhasi, R., Reich, D., 2023. Social and genetic diversity among the first farmers of central Europe. *bioRxiv* [preprint]. DOI: 10.1101/2023.07.07.548126

Golitko, M. and Keeley, L.H., 2007. Beating ploughshares back into swords: warfare in the Linearbandkeramik. *Antiquity*, 81 (312), 332-342.

Gosden, C., 2020. *Magic: a history: from alchemy to witchcraft, from the Ice Age to the present.* New York: Farrar, Straus and Giroux.

Hachem, L., 1996. Les ensembles funéraires rubanés de Menneville Derrière le Village (Aisne) : de la diversité du traitement des défunts a la cohérence d'un système. *Revue Archéologique de l'Est*, Dijon, 25-27 oct. 1991, 14eme supplément, 119-174.

Hofmann, D., 2015. Bruno Boulestin und Anne-Sophie Coupey, Cannibalism in the Linear Pottery culture: the human remains from Herxheim. *Bonner Jahrbücher* 215, 388-393.

Hofmann, D., 2020. LBK structured deposits as magical practices. In D. Hofmann, ed. *Magical, mundane or marginal? Deposition practices in the Early Neolithic Linearbandkeramik culture*. Leiden: Sidestone Press, 113-147.

Hofmann, D., Bentley, R.A., Bickle, P., Bogaard, A., Crowther, J., Cullen, P., Fibiger, L., Grupe, G., Hamilton, J., Hedges, R., Macphail, R., Nowell, G., Pechtl, J., Salque, M., Schultz, M., Whittle, A.W.R., 2012. Kinds of diversity and scales of analysis in the LBK. In M. Cladders, H. Stäuble, T. Tischendorf, S. Wolfram, eds. *Siedlungsstruktur und Kulturwandel in der Bandkeramik. Beiträge zur internationalen Tagung 'Neue Fragen zur Bandkeramik oder alles beim Alten?!' Leipzig, 23.-24. September 2010*. Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege. Beiheft. Dresden: Landesamt für Archäologie Freistaat Sachsen, 107-117.

Krause, R., 1998. Die bandkeramischen Siedlungsgrabungen bei Vaihingen an der Enz, Kreis Ludwigsburg (Baden-Württemberg). *Berichte der Römisch-Germanischen Kommission,* 79, 5-106.

Leppard, T.P., 2014. Mobility and migration in the Early Neolithic of the Mediterranean: questions of motivation and mechanism. *World Archaeology*, 46 (4), 484-501.

Leppard, T.P., 2021. Process and dynamics of Mediterranean neolithization (7000-5500 BC). *Journal of Archaeological Research*. DOI: 10.1007/s10814-021-09161-5

Mauss, M., 2001. *A general theory of magic*. 2nd edition. London and New York: Routledge.

Meyer, C., Knipper, C., Nicklisch, N., Münster, A., Kürbis, O., Dresely, V., Meller, H., Alt, K.W., 2018. Early Neolithic executions indicated by clustered cranial trauma in the mass grave of Halberstadt. *Nature Communications,* 9 (1), 2472.

Meyer, C., Kürbis, O., Alt, K.W., 2004. Das Massengrab von Wiederstedt, Ldkr. Mansfelder Land: Auswertung und Gedanken zur Deutung im Kontext der Linienbandkeramik. *Jahresschrift für mitteldeutsche Vorgeschichte*, 88, 31-66.

Meyer, C., Lohr, C., Gronenborn, D., Alt, K.W., 2015. The massacre mass grave of Schöneck-Kilianstädten reveals new insights into collective violence in Early Neolithic central Europe. *Proceedings of the National Academy of Sciences*, 112 (36), 11217-11222.

Moore, J., 2016. *The Rise of Cheap Nature*, in: Moore, J. ed., *Anthropocene or Capitalocene? Nature, History, and the Crisis of Capitalism*. PM Press, Oakland, CA, 78-115.

Müller-Scheeßel, N. and Hukeľová, Z., 2020. The burials and human remains from the LBK and Želiezovce settlement site of Vráble. In Furholt, M., Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheeßel, N. eds. *Archaeology in the Žitava Valley I: the LBK and Želiezovce settlement site of Vráble*. Leiden: Sidestone Press, 159-235.

Müller, J., Müller-Scheeßel, N., Cheben, I., Wunderlich, M., Furholt, M., 2020. On the demographic development of Vráble and the Upper Žitava Valley. In M. Furholt, Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheeßel, N. eds. *Archaeology in the Žitava Valley I: the LBK and Želiezovce settlement site of Vráble*. Leiden: Sidestone Press, 493-502.

Müller-Scheeßel, N., Schmitz, J., Hofmann, R., Kujundžić-Velzagić, Z., Müller, J., Rassmann, K., 2009. Die Toten der spätneolithischen Tellsiedlung von Okolište Bosnien-Herzegowina. Massaker, Seuche oder Bestattungsbrauch? In A. Zeeb-Lanz, ed. *Krisen Kulturwandel Kontinuitäten. Zum Ende der Bandkeramik in Mitteleuropa. Beiträge zur internationalen Tagung in Herxheim bei Landau (Pfalz) am 14.-17.06.2007.* Rahden: Verlag Marie Leidorf GmbH, 327-340.

Müller-Scheeßel, N., Hukeľová, Z., Meadows, J., Cheben, I., Müller, J., Furholt, M., 2021. New burial rites at the end of the Linearbandkeramik in south-west Slovakia. *Antiquity,* 95 (379), 65-84.

Nieszery, N., 1995. *Linearbandkeramische Gräberfelder in Bayern*. Rahden: Verlag Marie Leidorf GmbH.

Orschied, J. and Haidle, M.N., 2012. Violence against the living, violence against the dead on the human remains from Herxheim, Germany: evidence of a crisis and mass cannibalism? In R.J. Schulting and L. Fibiger. eds. *Sticks, stones, and broken bones: Neolithic violence in a European perspective*. Oxford, New York: Oxford University Press, 101-120.

Pickartz, N., Rabbel, W., Rassmann, K., Müller-Scheeßel, N., Furholt, M., Müller, J., Cheben, I., Wilken, D., Wunderlich, T., Dreibrodt, S., 2020. What over 100 drillings tell us: a new method for determining the Koenigsberger ratio of soils from magnetic mapping and susceptibility logging. *Archaeological Prospection,* 27 (4), 393-414.

Riedhammer, K., 2019. The radiocarbon dates from Herxheim and their archaeological interpretation. In A. Zeeb-Lanz, ed. *Ritualised destruction in the Early Neolithic: the exceptional site of Herxheim (Palatinate, Germany)*. Volume 2. Speyer: GDKE, Direktion Landesarchäologie, 285-303.

Seregély, T., 2012. Neolithische Siedlungen und vergessene Funde : Neues zur Jungfernhöhle bei Tiefenellern. *In:* Falkenstein, F., ed. *Hohler Stein, Rothensteine und Jungfernhöhle : Archäologische Forschungen zur prähistorischen Nutzung naturheiliger Plätze auf der Nördlichen Frankenalb*. Würzburg: Institut für Altertumskunde, 64-73.

Sørensen, J., 2006. *A cognitive theory of magic: annotated edition*. Lanham, MD: AltaMira Press.

Tambiah, S., 1990. *Magic, science and religion and the scope of rationality*. Cambridge and New York: Cambridge University Press.

Teschler-Nicola, M., 2012. The Early Neolithic site Asparn/Schletz (Lower Austria): anthropological evidence of interpersonal violence. In R.J. Schulting and L. Fibiger, eds. *Sticks, stones, and broken bones: Neolithic violence in a European perspective*. Oxford and New York: Oxford University Press, 101-120.

Turck, R., 2019. Where did the Herxheim dead come from? Isotopic analysis of human individuals. *In:* A. Zeeb-Lanz, ed. *Ritualised destruction in the Early Neolithic: the exceptional site of Herxheim (Palatinate, Germany)*. Volume 2. Speyer: Rheinland-Pfalz Generaldirektion kulturelles Erbe, Direktion Landesarchäologie, 313-421.

Wahl, J. and Trautmann, I., 2012. Neolithic massacre at Talheim: a pivotal find in conflict archaeology. *In:* R.J. Schulting and L. Fibiger, eds. *Sticks, stones, and broken bones: Neolithic violence in a European perspective*. Oxford and New York: Oxford University Press, 77-100.

Wahl, J., König, H.G., Biel, J., 1987. Anthropologisch-traumatologische Untersuchung der menschlichen Skelettreste aus dem bandkeramischen Massengrab bei Talheim, Kreis Heilbronn. *Fundberichte aus Baden-Württemberg*, 12, 65-193.

Windl, H., 1994. Zehn Jahre Grabung Schletz, VB Mistelbach, NÖ. *Archäologie Österreichs*, 5 (1), 11-18.

Winkelmann, K., Bátora, J., Hohle, I., Kalmbach, J., Müller-Scheeßel, N., Rassmann, K., 2020. Revealing the general picture: magnetic prospection on the multiperiod site of Vráble 'Fidvár'/'Veľké Lehemby'/'Farské'. *In*: M. Furholt, Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheeßel, N. eds. *Archaeology in the Žitava Valley I: the LBK and Želiezovce settlement site of Vráble*. Leiden: Sidestone Press, 33-51.

Wunderlich, M., Müller, J., Cheben, I., Bistáková, A., Furholt, M., Müller-Scheeßel, N., 2020. The political economy of Vráble. *In:* M. Furholt, Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheeßel, N. eds. *Archaeology in the Žitava Valley I: the LBK and Želiezovce settlement site of Vráble*. Leiden: Sidestone Press, 511-531.

Zeeb-Lanz, A. ed., 2016. *Ritualised destruction in the Early Neolithic: the exceptional site of Herxheim (Palatinate, Germany)*. Volume 1. Speyer: Rheinland-Pfalz Generaldirektion kulturelles Erbe.

Zeeb-Lanz, A. ed., 2019. *Ritualised destruction in the Early Neolithic: the exceptional site of Herxheim (Palatinate, Germany).* Volume 2. Speyer: Rheinland-Pfalz Generaldirektion kulturelles Erbe., Direktion Landesarchäologie.

Exploring the Late Neolithic ditch: New data on dating, subsistence and environment from a circular enclosure at Borđoš (Vojvodina, Serbia)

Robert Hofmann, Aleksandar Medović, Slobodan B. Marković, György Sipos, Sarah Pleuger-Dreibrodt, Randall J. Schaetzl, Milivoj B. Gavrilov, Milica G. Radaković, Ildiko Medović, Desanka Kostić, Stefan Dreibrodt, Fynn Wilkes, Tijana Stanković Pešterac, Martin Furholt

Abstract

The interdisciplinary archaeological and geoarchaeological investigations performed at the Neolithic site of Borđoš, near Novi Bečej, on the Upper Pleistocene terrace near the River Tisza focused on an enclosure system belonging to a circular ditched enclosure on the edge of the Late Neolithic archaeological settlement mound. Our research comprised sedimentological, geomorphological, pedological and archaeological investigations; archaeobotanical and zooarchaeological analyses; as well as numerical luminescence and radiocarbon dating. Based on these data, this paper attempts to clarify chronological and functional aspects of the backfilling processes of the ditch system in relation to other components of the site. According to a largely consistent series of ^{14}C dates obtained from secure contexts and short-lived sample material from a small excavation, the ditches were backfilled over a very short period of time around 5000 BCE. This dating stands in striking contrast not only to some luminescence dates from the same excavation, but also to two ^{14}C dates from drilling cores previously interpreted as outliers. These new dates suggest the ditches date 1500 years earlier, around the middle of the 7th millennium BCE. Our paper discusses these challenging early dates for the settlement activities at Borđoš in the broader context of the chronology of the south-east European Neolithic and the dating of other circular ditch systems. There is a high probability that the very early dates, in fact, are not related to the construction and the use of the circular enclosure system but the result of specific, intentional backfilling processes of

the ditches, which led to incomplete bleaching of the deposited soil material and the deposition of old wood. Nevertheless, the rondel of Borđoš is a very early example of such an enclosure system. The ditches provide a valuable archive for the reconstruction of functional aspects of a communal integrative institution and the prehistoric environment. Sedimentary, pedogenic and botanical characteristics provide clear evidence for a semi-open landscape on the loess terraces, embedded in wooded floodplains.

Keywords: *Late Neolithic, Vojvodina, Pannonian Plain, circular enclosures, OSL dating, ¹⁴C dating, drilling, archaeo-magnetic survey, archaeological excavation, zooarchaeology, archaeobotany, environmental reconstruction, chernozem*

Introduction

The long-term process of the introduction of an agro-pastoral economy to south-eastern Europe, starting from 6400 BCE, entailed major challenges for the societies involved. Prior to this process, sparsely populated landscapes were cleared for the requirements of agriculture and animal husbandry, and adaptations were made to people's mode of subsistence according to the specific resources of the environments being appropriated (*e.g.* Barker 1975; Ivanova *et al.* 2018). Starting from the middle of the 6th millennium BCE, however, the increasing size of populations and their concentration in increasingly larger local communities with hundreds or even thousands of inhabitants required the creation of new political mechanisms and institutions to cope with the increased social complexity and scalar stress in these settlements (Tringham and Krstić 1990; Müller 2006; Porčić 2011; Hofmann 2013; Porčić *et al.* 2020). In both the social and the economic sphere, people found different local and regional solutions to these challenges.

In spite of many famous Neolithic sites investigated in Serbia and multiple efforts to reconstruct the subsistence of Neolithic communities, our knowledge about the climatic and environmental conditions the people of this period were faced with is still relatively limited (cf. Chapman 2018). This in particular applies to the Vojvodina, in the south-eastern part of the Pannonian Plain, with its very specific environment, which is strongly influenced by the activity of the rivers Tisza, Timiş and Danube (cf. Borojević 2006).

In this region, the long-term social and economic development of human societies and the gradual exploitation, appropriation and transformation of the environment started around 6200 BCE (Biagi *et al.* 2005; Porčić 2020). This development can be seen on, among other things, the spatial micro-scale of a Late Pleistocene Terrace formed by the activity of the River Tisza south of Novi Bečej, which is being investigated in an ongoing, long-term Serbian – German cooperation.

The focus of these investigations is the large Neolithic settlement of Borđoš, a complex made up of different, spatially separated settlement components developed over a roughly 600-year period. Alongside a 9 ha artificial settlement mound and a flat settlement with an originally 40 ha extension, there is also a circular enclosure (Medović *et al.* 2014; Hofmann *et al.* 2019). Along with other components of the settlement, this enclosure has been the subject of archaeo-magnetic, archaeological, botanical, zoological, sedimentological and geoarchaeological investigations.

This paper brings together multiple aspects of our interdisciplinary analyses of this circular enclosure, such as size, shape, stratigraphy, sedimentation, material culture and attempts to reconstruct the natural conditions and subsistence strategies to evaluate (1) the extent to which the fill of the ditch can serve as a source for the reconstruction of the Neolithic subsistence economy and environment in the lower reaches of the River Tisza and (2) the importance of the site in the context of other European circular enclosures.

Circular enclosures (also called rondels) are a specific type of mostly small ditch systems (with diameters ranging from 30 to 240 m) that usually occur within or next to settlements (Řídký *et al.* 2019; Vondrovský *et al.* 2022). They show circular ground plans with one to five parallel ditches; regularly arranged entrances, frequently on two or four opposite sides; and palisades. Most scholars assume that these circular enclosures do not represent regular settlements but facilities with special functions, such as cattle kraals or places for astronomical observations, games, ritual or socially integrative or competitive activities (*e.g.* Petrasch 1990; Plath 2012; Řídký *et al.* 2019; Vondrovský *et al.* 2022). The available ^{14}C evidence reveals that most of the circular enclosures were used for only a short time and then abandoned and backfilled, mainly within the narrow window of time between 4800 and 4700 BCE.

Circular enclosures show a wide geographical distribution in regions in central and south-east central Europe with different Neolithic pottery styles, and it has not been clear until now exactly where this phenomenon originated. They are concentrated in central Germany, Saxony, Bohemia (stroke-ornamented ware); Bavaria (south-east Bavarian Middle Neolithic); Moravia; Lower Austria (Moravian-Austrian Painted Ware group); and Transdanubia (Lengyel). The distribution limits are the River Danube in the east and the River Drava in the south. However, recently in Slavonia and in the Romanian Banat, new finds of circular enclosures and circular settlements have been made through aerial archaeology and archaeo-magnetic survey (*e.g.* Lazarovici 2013; Kalafatić and Šiljeg 2018). These sites have only just started to be investigated and therefore have not yet found their way into syntheses.

An exception and a special case are the much better investigated circular enclosures of the Csőszhalom group in the Upper Tisza region, which represent tell components within larger flat settlements (*e.g.* Raczky *et al.* 2010; Raczky *et al.* 2011). Inside these enclosures, small settlement mounds accumulated due to repeated, dense development of the enclosure's interior space. In the case of Polgár-Csőszhalom, the existence of a building with an unusual finds inventory and construction indicates that the circular enclosure may have represented an area with special functions within a much larger settlement (Raczky and Sebők 2014). Alternatively, the greater accumulation of settlement layers could also be due to the longer use of these facilities compared with the surrounding flat settlements (Raczky *et al.* 2015; Hofmann *et al.* 2019).

Borđoš and the surrounding micro-region

Originally, the River Tisza occupied a position near the eastern margin of the Pannonian (Carpathian) Basin during the Early – Middle Pleistocene period. Due to relatively more intense subsidence in the central part of the basin, the river shifted its position during the Late Pleistocene in a westward direction, to its current valley (Nádor *et al.* 2003; Vandenberghe *et al.* 2018). The site of Borđoš is located at the transition between the modern alluvial plain and a terrace shaped by River Tisza erosion after incision at the end of the last glaciation, and a significant part of the western and north-western areas of the Neolithic site were later destroyed by the River Tisza.

The location of Borđoš, close to the transition between these two geomorphological units, provided many benefits to Neolithic people. Starting from the late 7th or the first half of the 6th millennium BC, human communities with a Neolithic economy and the Starčevo pottery style inhabited the river terrace Borđoš is located on. From this Early Neolithic period, we know of six smaller settlements, widely distributed in the floodplain of the River Tisza and on the terrace, forming a dispersed regional network of small and probably relatively short-lived communities (Fig. 1).

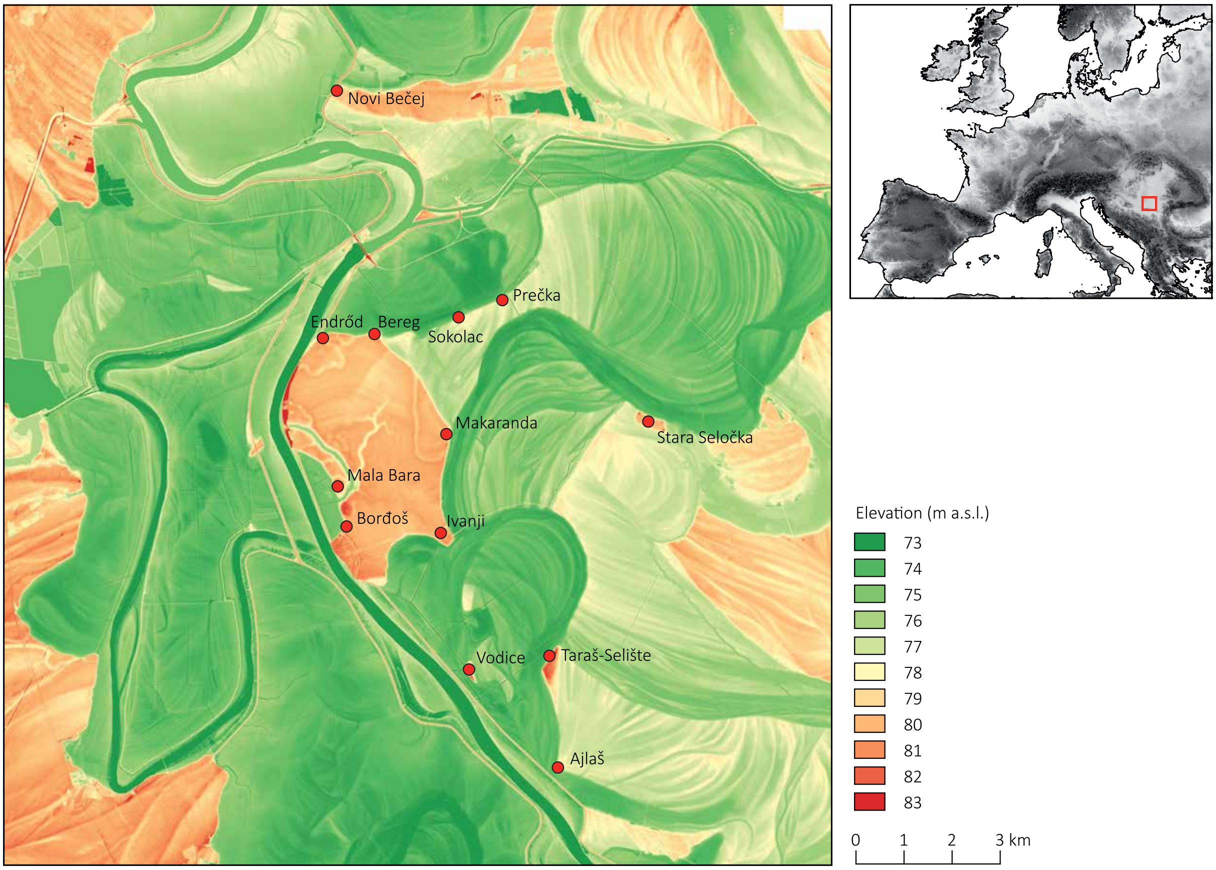


Figure 1. Digital elevation model of the Borđoš terrace (in the centre) and the surrounding part of the Tisza Valley, with Pleistocene (in the east) and Holocene (in the west) river channels and Neolithic sites mentioned in the text.

Around 5350 BCE, a process of population agglomeration began in large parts of south-eastern Europe and in the Carpathian Basin, which led to a significant reduction in the number of settlements, more people being concentrated in fewer sites, and the establishment of more solid and permanent houses (Tringham and Krstić 1990; Parkinson and Gyucha 2012; Chapman 2020, 157-194, 277-312). This development is also visible in the Borđoš micro-region in several respects. As demonstrated, for example, for the settlement of Makaranda, located on the eastern edge of the terrace, Early and Middle Neolithic settlements were gradually abandoned (Wilkes 2019), and at the same time, as has just recently been outlined and regionally contextualised based on a series of 39 ^{14}C dates, the site of Borđoš, initially 9 ha in size and including the circular enclosure discussed in this paper, was founded on the south-western part of the terrace (Medović *et al.* 2014; Hofmann *et al.* 2019).

The emergence of the large, multicomponent settlement complex of Borđoš is thus at least partly the result of process of population concentration, which continued until approximately 4700 BC. This process reached its peak between about 4850 and 4700 BCE, reflected at Borđoš in the extension of the settlement area by an extensive flat settlement temporarily 40 ha in size (Fig. 2). At that time, the only site that existed apart from Borđoš was Prečka, on the northern edge of the terrace (Wilkes 2019).

Both the tell and the flat settlement of Borđoš were enclosed by complex and multiphased enclosure systems. In the case of the flat settlement, this enclosure system was accessible through numerous entrances. Both the tell and the flat settlement showed a hitherto unknown centripetal settlement plan, in which houses were oriented towards an open square in the centre of the settlement (Hofmann *et al.* 2019). We assume that this central space acted as a kind of arena for the negotiation of communal concerns.

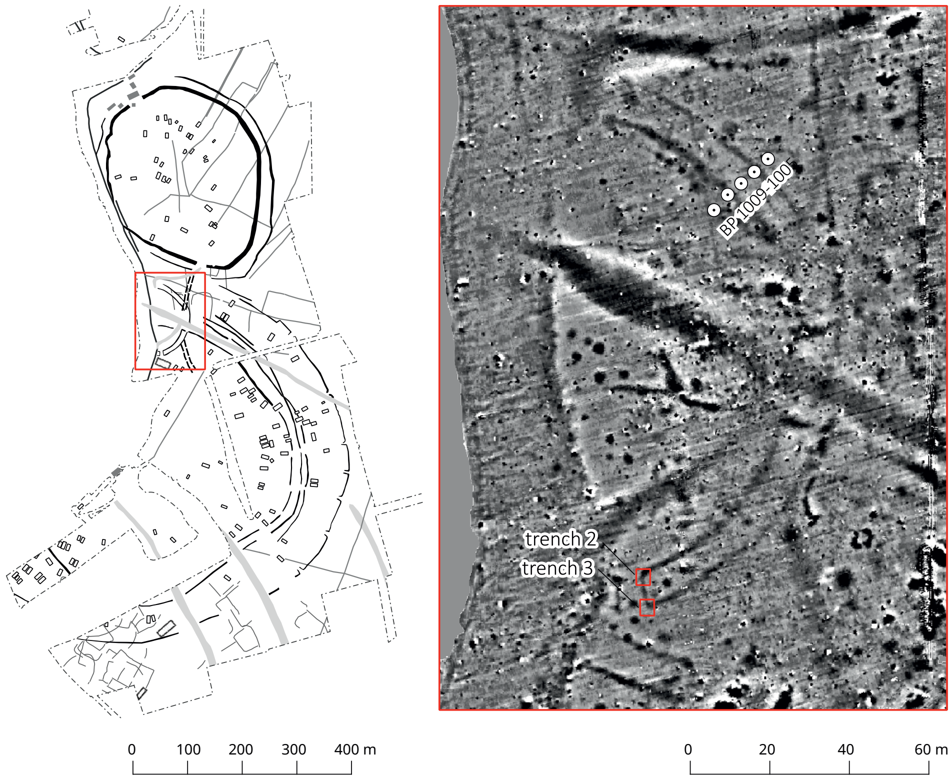


Figure 2. Borđoš. Overview map showing the location of the enclosure within the reconstructed Neolithic settlement plan (left) and geophysical plot of the circular enclosure showing the location of the trenches (right).

After 4700 BCE, we observe indications of a crisis in large parts of the Pannonian Plain and south-eastern Europe, which led to a decline in population size and finally, in the 46th century BCE, to the collapse of the Late Neolithic settlement system and the constitution of Early Copper Age settlement patterns (*e.g.* Link 2006; Borić 2015). At Borđoš, the large, flat settlement was abandoned and for a time only the tell component continued to be inhabited. Subsequently (after 4600 BCE), as far as we know, the river terrace remained unpopulated for a longer period.

Materials and methods

At Borđoš, an area of 51 ha has been archaeo-magnetically surveyed using the SENSYS MAGNETO® MX V3 Survey System of the SENSYS Sensorik & Systemtechnologie GmbH, Bad Saarow, Germany. The device was used with eight sensors, which were installed at 0.5 m intervals on a wheel cart pushed by two persons. The geomagnetic device was coupled to a GPS system (Leica, GNSS/GPS systems Viva GS 10), enabling continuous grid measurements (zig-zag) in a short amount of time.

Five sediment cores were drilled on a transect through the north-eastern part of the ditch system, with a percussion drilling system. The sediment cores were documented according to field work manuals (AG Boden 2005), and charcoal pieces were selected for radiocarbon dating. For core 1008 (fill of the outer ditch) standard field and laboratory methods were applied to characterise the fill and infer the filling processes. Those methods included drying the samples at room temperature and then separating the < 2 mm fraction with the help of a mortar and pestle and 2 mm mesh. During this step, stones, daub, bone fragments, charcoal and mollusc shells were carefully separated from the rest of the matrix and their weight was documented. Some standard sediment analyses were carried out on the < 2 mm fraction. Loss on ignition (LOI) was determined by heating a dried portion of the sample (105 °C overnight) at 550 °C (LOI 500), respectively 940 °C (LOI 940), for two

hours each. The loss of weight is considered to reflect the content of organic matter (LOI 500) and carbonates (LOI 940) (Dean 1974). Sediment colours were determined with the help of a Voltcraft Plus RGB-2000 Color Analyzer device (Rabenhorst *et al.* 2014; Sanmartín *et al.* 2014). Since values of RGB colour measurements are internally highly correlated, the raw RGB values were transferred into hue, light and chromatographic information following Viscarra Rossel *et al.* (2006) prior to statistical analysis.

Magnetic susceptibility was measured on 10 ml of the homogenised < 2 mm samples using a Bartington MS2B susceptibility meter (resolution 2*10–6 SI, measuring range 1-9999*10–5 SI, systematic error 10%). Measurements were carried out at low (0.465 kHz) and high (4.65 kHz) frequency. A 1% Fe_3O_4 (magnetite) was measured regularly, and the samples' susceptibility values were calibrated using this standard before the mass-specific susceptibility was calculated based on the weight of the 10 ml samples. The frequency-dependent susceptibility was calculated according to Dearing (1999). Statistical analysis of the results was carried out using the software PAST (Hammer *et al.* 2001).

We used the archaeo-magnetic plan to target areas for stratigraphic excavation. Removed contexts were documented as 'features', by which we mean units that can be distinguished from one another based on material properties, such as the type of soil substrate; its colouring; and the type, size and quantity of admixtures contained therein (Hofmann 2013, 52). The localisation of the finds was either performed using xyz coordinates (single finds, samples) or according to a grid system (all) with an interval of 1 m. In addition, we made an assignment to features and levels, which usually allows for a more precise attribution and interpretation of depositional processes in larger archaeological contexts. The reference points for the excavation, which were recorded with a differential GPS GNS from Leica, show an averaged systematic height deviation of about +48.25 m (±0.15 m) compared with the digital terrain model of the Serbian National Geodetic Agency. All height values reported in this article were corrected by this value.

Archaeological artefacts – in this case pottery pieces and chipped stone artefacts – can provide information about activities carried out with the help of the artefacts. For this purpose it is necessary not only to reconstruct the depositional and post-depositional processes, but also, in the case of pottery, to study technological characteristics and vessel shapes by macroscopic methods in order to obtain indications of their function. In the case of chipped stone artefacts, the study was limited provisionally to their typological classification. The reconstruction of depositional circumstances is based on the terminology used by Ulrike Sommer (1991), who distinguished among primary, secondary and foreign waste according to the original place of use.

We undertook contextual sampling for macro-botanical remains by taking soil samples (4-6 litres of substratum per sample) during the excavation. Furthermore, several pieces of charred wood could be observed and were hand-picked for the analyses. Manual flotation of the samples was carried out in Novi Bečej, after which the carbonised plant material taken to the Museum of Vojvodina in Novi Sad and left to slowly dry for several days in a dry, dark place. It was later analysed using low-power (7-45×) microscopes. Identification of charred and mineralised seeds and one-seeded fruits was assisted by The Digital Seed Atlas of the Netherlands (Cappers *et al.* 2012). Identification of charred wood was assisted by the wood anatomy key (Schoch *et al.* 2004).

The zooarchaeological remains were curated at the Museum of Vojvodina in Novi Sad. The hand-collected remains of molluscs, fish, reptiles and mammals were examined and identified by Sarah Pleuger-Dreibrot, using the museum's zooarchaeological collection. Besides undergoing basic and complete zooarchaeological recording, bovid teeth were classified for age estimation based on Grant (1982) and interpreted using the age scheme by Legge (1992). Fracture surfaces on bone fragments were recorded

and classified using the fracture patterns scheme by Outram (2001). Ichthyological identifications were confirmed using the digital Archaeological Fish Resource comparative collection of the University of Nottingham's Archaeological Fish Resource.

We obtained 39 ^{14}C dates mostly from short-lived sample material, from the drilling cores and from all excavation areas (Hofmann *et al.* 2019). These dates provide reliable information on the temporal and spatial development of the Borđoš settlement complex through calibration and modelling using the boundary function of the software OxCal 4.3 and the INTCAL20 calibration curve (Bronk Ramsey 2009; Reimer *et al.* 2020). We obtained a total of 9 ^{14}C dates from samples from the ditches of the circular earthwork: 3 from drilling core BP1008 and 6 from excavation Trenches 2 and 3. All dates derive from the fill of the ditches and thus represent a terminus ante quem for the use of the circular enclosure complex.

For luminescence dating, we collected six samples from ditch deposits in the south profile of Trench 2. The preparation of samples followed usual laboratory techniques (*e.g.* Mauz *et al.* 2002). All procedures were carried out in subdued yellow light provided by low-pressure Na lamps. Water content was determined using the formula of (mw-md)/md, where mw and md are wet and dry weight of the sample, respectively. The fine grain technique was applied, the 4-11 and 11-20 µm fractions which were separated by settling. The carbonate and organic material content was removed by repeated treatment in 10% HCl and 10% H_2O_2. The abundance of quartz in the samples was enhanced by 7 days of etching in H2SiF6. Several aliquots of the same optically stimulated luminescence (OSL) dating samples were prepared by pipetting 2 mg of sample in suspension on aluminium discs.

OSL ages are calculated from the ratio of the absorbed total dose (palaeo-dose or its laboratory equivalent), recorded by the amount of trapped charge, and dose rate, being the annual amount of radioactive dose reaching the mineral grains. OSL measurements themselves aim to determine the amount of absorbed dose by generating a function between laboratory doses and subsequent luminescence responses (dose-response curve). To determine the value of the absorbed total dose (equivalent dose – De) a RISØ DA-20 TL/OSL type luminescence reader was used (Bøtter-Jensen *et al.* 2010) and the single-aliquot regeneration (SAR) protocol was applied (Murray and Wintle 2003). Stimulation was carried out using blue (470 nm) LEDs, while detection was made through a U-340 filter. The suitability of the samples for dating was tested by comparing decay curves to that of the RISØ calibration quartz and by performing dose-recovery tests at different preheat temperatures. The first was made to check the dominance of the fast component, the second to investigate whether known doses can be precisely determined or recovered by the SAR protocol. Finally, SAR measurements were performed using 200°C/160°C preheat/cut heat treatment on 12 aliquots per sample. Dose points were fitted with a single-saturating exponential function. Standard rejection criteria (Murray and Wintle 2000; Duller 2003) were used to select aliquots for further calculations (recycling ratio: 1.00±0.10; maximum dose error: 10%; maximum recuperation: 5%; maximum IR/OSL depletion ratio: 5%). Sample De was given as the mean and standard error of single-aliquot De values. Values were plotted on abanico plots (Dietze *et al.* 2016) generated in the R luminescence package (Kreutzer *et al.* 2012). Environmental dose rate (D*) was determined by using high-resolution, extended-range gamma spectrometry (Canberra XtRa Coaxial Ge detector), using 500 cm^3 Marinelli beakers. Dry dose rates were calculated using the conversion factors of Adamiec and Aitken (1998). Effective α dose rate was calculated by using a 0.04±0.02 a-value (Mauz *et al.* 2006). Attenuation factors for α and β dose rates were given after Brennan *et al.* (1991) and Brennan (2003), respectively. Wet dose rates were assessed on the basis of in-situ water contents (Aitken 1985). The rate of cosmic radiation was determined on the basis of burial depth, following the equation of Prescott and Hutton (1994).

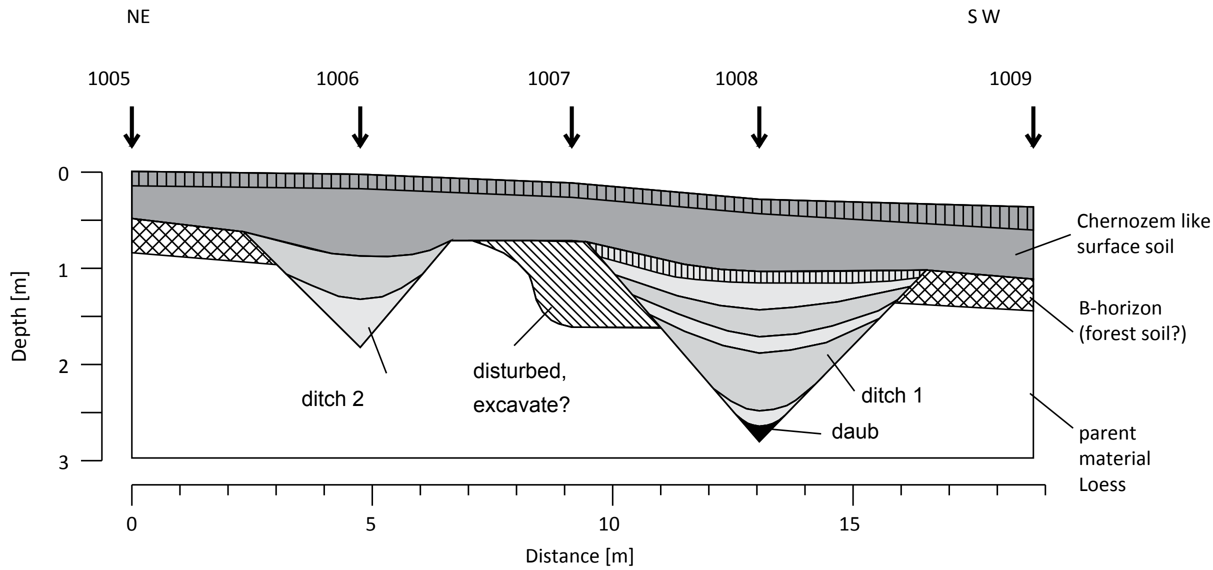


Figure 3. Borđoš. Sketch of sediments and soil horizons present in the cores drilled through the north-eastern section of the ditch system. Pr=profile.

Results

Magnetic survey

The semi-circular, rondel-like enclosure discussed in this paper was discovered through archaeo-magnetic survey in spring 2014 (Medović *et al.* 2014). According to the magnetic plan, the enclosure is located 40 m south-south-west of the Borđoš settlement mound (Fig. 2). It is composed of two ditches that run parallel to each other 6-7 m apart. Today, this structure measures 0.8 ha (enclosed area 0.52 ha), but a large part of the enclosure was lost due to lateral erosion of the Tisza towards the formerly existing riverbed (which is today silted up). If the rondel was originally circular, which seems a likely assumption, the diameter of the existing structure (135 m, enclosed area 115 m) suggests an original area of ca. 1.4 ha, with 1 ha within the area enclosed by the ditches.

In the south, both ditches of the circular ditch system are interrupted over a length of about 5.5 m. The ends of the ditches are interconnected on both sides by radially running ditch segments marking the location of an entrance or gate. Due to numerous disturbances, we are currently unable to determine with certainty whether other entrances were located in the east and north of the enclosure.

The interior surface of the circular ditch system shows no interpretable anomalies on the magnetic prospection image, with the exception of a few ditches (which run from the outside into the area of the enclosure) and several dot-like anomalies. Outside the circular enclosure, directly in front of its entrance, two linear anomalies run parallel to each other over a length of at least 28 m, with a distance of 11 m between them. According to our interpretation, this anomaly may represent wall trenches of a large Late Bronze Age house, in analogy to other houses in the southern part of the flat settlement.

Sediment cores

Sequences of archaeological layers and soil horizons were found in the drilled sediment cores (Figs. 2 and 3). Cores 1005 and 1009, taken next to the ditch system, contained a sequence of the soils that have formed at the site. The base is formed by the loess which is constituting the parent material. In its upper part, a buried,

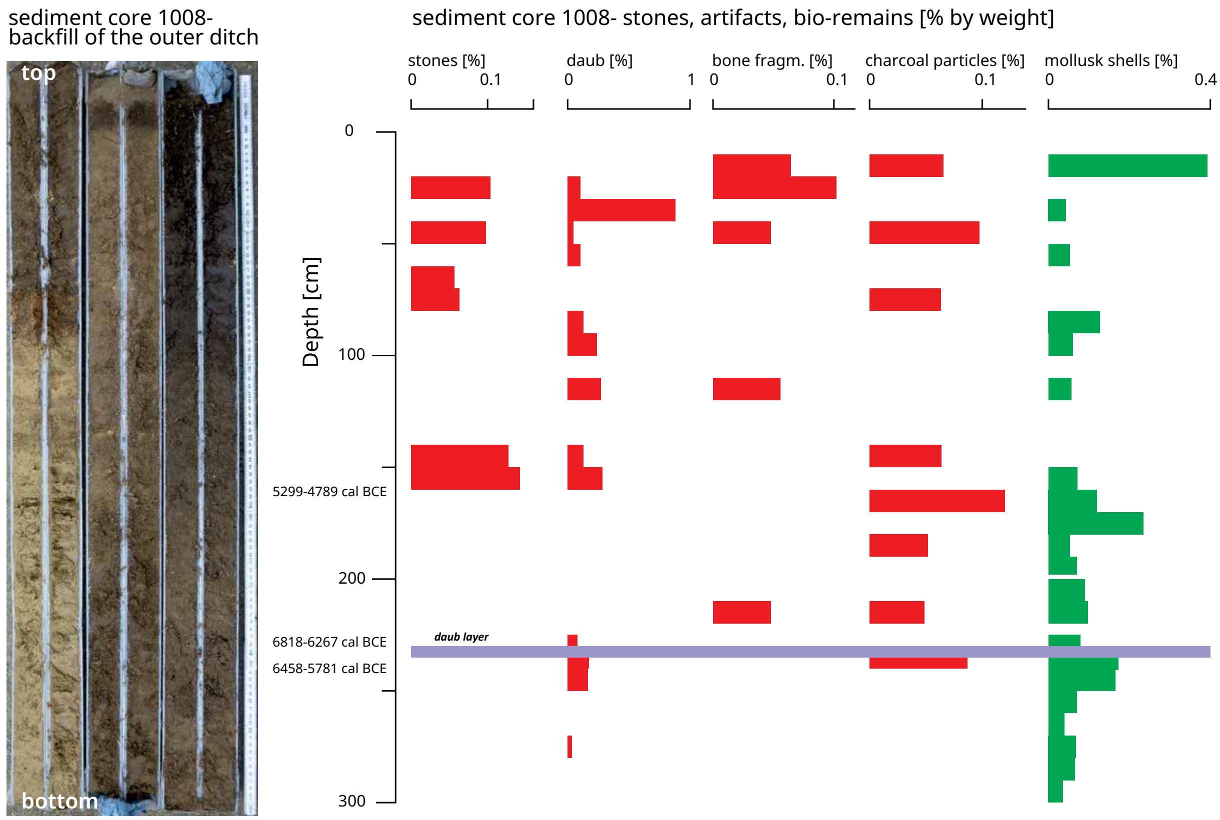


Figure 4. Borđoš, Core 1008. Photograph of the entire core (left) and the distribution of stones, artefacts and bio-remains retrieved from it (right).

weakly developed cambic B-horizon was found (thickness ca. 30 cm). Above the prehistoric surface soil, a chernozem-like soil has been found, varying in thicknesses between 40 and 50 cm. Cores 1006 to 1008 contain remnants of the former ditch system. While cores 1006 and 1008 contain the backfill of the inner and outer ditches, core 1007 contains a sequence of layers probably disturbed by prehistoric digging activities. The overall texture of the sediment is loamy silt, reflecting the properties of the parent material. The backfill of the ditches is characterised by a higher content of organic material, mixed with remnants of settlement activity (*e.g.* stones, daub, charcoal, bone fragments).

Core 1008 was selected for laboratory analysis (Fig. 4). It contains the loess at its base. Above that, at a depth of 235 cm, a compact layer of daub forms the base of the ditch backfill. A sequence of layers enriched in organic material and some remnants of settlement activity make up the backfill (235-240 cm below the surface). A chernozem-like surface soil has formed in the upper 40 cm of the profile. ^{14}C dating of charcoal pieces from the base of the ditch backfill resulted in early Holocene ages (Fig. 4). Another charcoal piece, at a depth of 158 cm, dates to the early mid-Holocene.

In general, the backfill is relatively low in objects indicating prehistoric settlement activity (note the % by weight values) (Fig. 5). Their occurrence is mostly restricted to the backfill and the recent surface soil. Some daub pieces within the loess may be a result of bioturbation post-dating to prehistoric settlement. The mollusc shells (almost exclusively small snail shells), which are present throughout the sequence, probably naturally occurred at the site.

The sediment properties clearly reflect the change from the loess at the base to the backfill sediment. The backfill sediment is much darker (lower RGB values), contains more organic matter (higher LOI 500 values), and has higher magnetic susceptibility values. The latter are visible in the raw mass-specific susceptibility data as well as in the frequency-dependent susceptibility. Frequency-dependent magnetic susceptibility is considered to reflect different sizes of magnetic particles

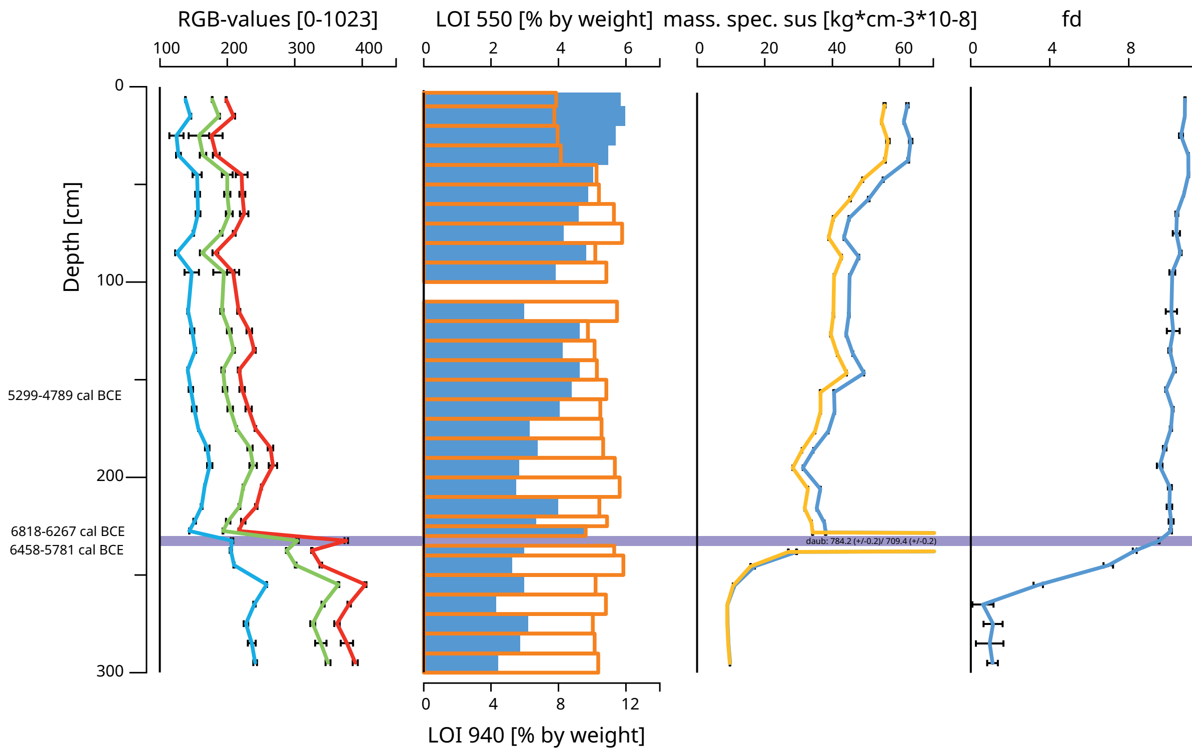
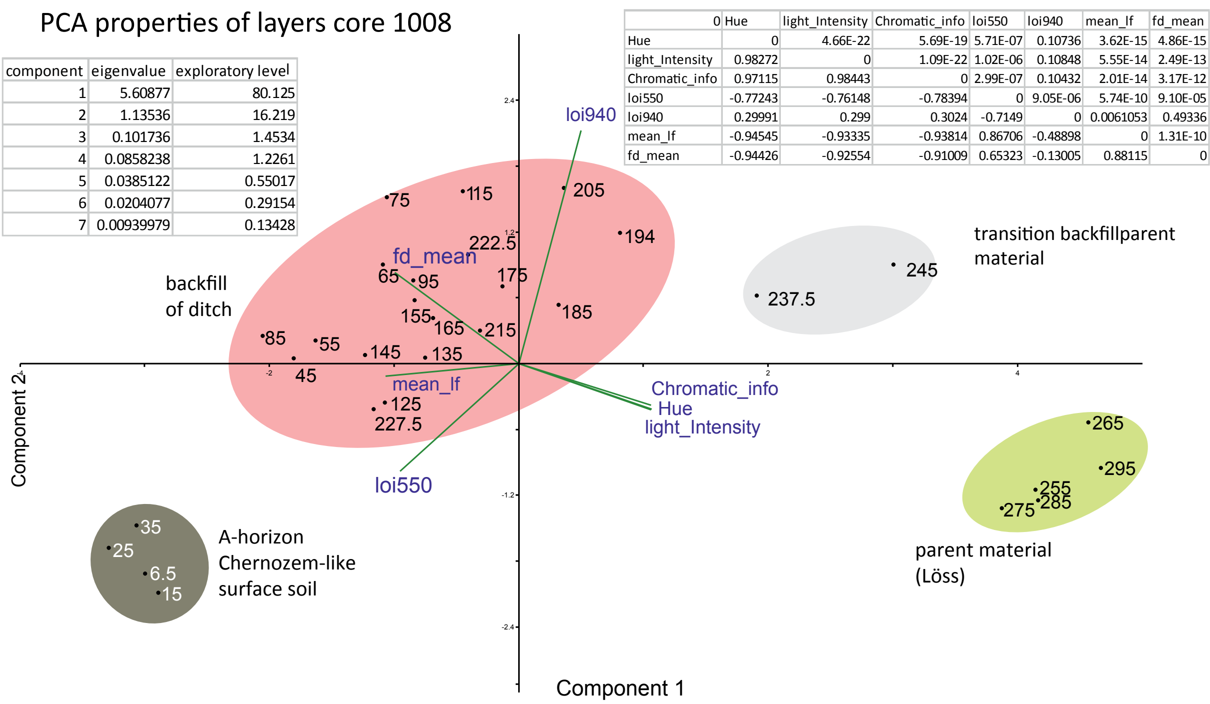


Figure 5. Borđoš, Colour, LOI (blue, filled: LOI 550; orange, open: LOI 940), massspecific magnetic susceptibility (orange: low frequency; blue: high frequency) and frequency dependent magnetic susceptibility (fd) of core 1008.

and thus to give hints about sources of magnetism within sediments (Clark 1996; Dearing 1999). Within the backfill of the ditch, a certain variability is visible. Perhaps the paler colours, the lower organic matter content and the lower magnetic susceptibility values in its lower part (ca. 230 to 170 cm) reflect internal division of backfill layers of different properties or age. We were unable to prove or disprove this with the available data. The overall high content of the backfill in carbonates (LOI 940) could reflect both initially high carbonate contents and secondary enrichment in carbonates as a post-depositional process. The chernozem-like surface is characterised by darker colours, higher content in organic matter, lower content in carbonates and higher magnetic susceptibility values.

A statistical analysis of the laboratory results from core 1008 is given in Fig. 6. The groups resulting from the principal components analysis (based on correlation) clearly reflect the sequence of loess, the backfill of the ditch and the chernozem-like surface soil. Within the ditch backfill, no significant division is evident based on the available data. The summary magnetic susceptibility plot gives an indication for magnetic enrichment of the backfill by organic matter decomposition rather than by a significant admixture of burnt particles (note the much higher value of a piece from the basal daub layer and the low amount of daub particles in the sediment; Fig. 6). With some exceptions, the magnetic properties correlate with sediment depths. This indicates that part of the magnetic enhancement is post-depositional. This process of enhancement of organics-rich backfills by organic matter decomposition is considered as a source of induced and remanent magnetism (Pickartz *et al.* 2020), and this may explain why such archaeological items (filled-in ditches, pits, *etc.*) are visible in gradiometer measurements.

It is possible that the backfill of the ditch contains layers of different properties and/or ages, but any further differentiation within the fill is impossible with the data available. If there were multiple phases of ditch fill, they very probably occurred during the short period of Neolithic settlement at the site. This is clear from the overall similar properties of the backfill and indicated by the observed age-depth trend in the magnetic properties (Fig. 6). The topsoil chernozem has formed after



component	eigenvalue	exploratory level
1	5.60877	80.125
2	1.13536	16.219
3	0.101736	1.4534
4	0.0858238	1.2261
5	0.0385122	0.55017
6	0.0204077	0.29154
7	0.00939979	0.13428

0	Hue	light_Intensity	Chromatic_info	loi550	loi940	mean_lf	fd_mean
Hue	0	4.66E-22	5.69E-19	5.71E-07	0.10736	3.62E-15	4.86E-15
light_Intensity	0.98272	0	1.09E-22	1.02E-06	0.10848	5.55E-14	2.49E-13
Chromatic_info	0.97115	0.98443	0	2.99E-07	0.10432	2.01E-14	3.17E-12
loi550	-0.77243	-0.76148	-0.78394	0	9.05E-06	5.74E-10	9.10E-05
loi940	0.29991	0.299	0.3024	-0.7149	0	0.0061053	0.49336
mean_lf	-0.94545	-0.93335	-0.93814	0.86706	-0.48898	0	1.31E-10
fd_mean	-0.94426	-0.92554	-0.91009	0.65323	-0.13005	0.88115	0

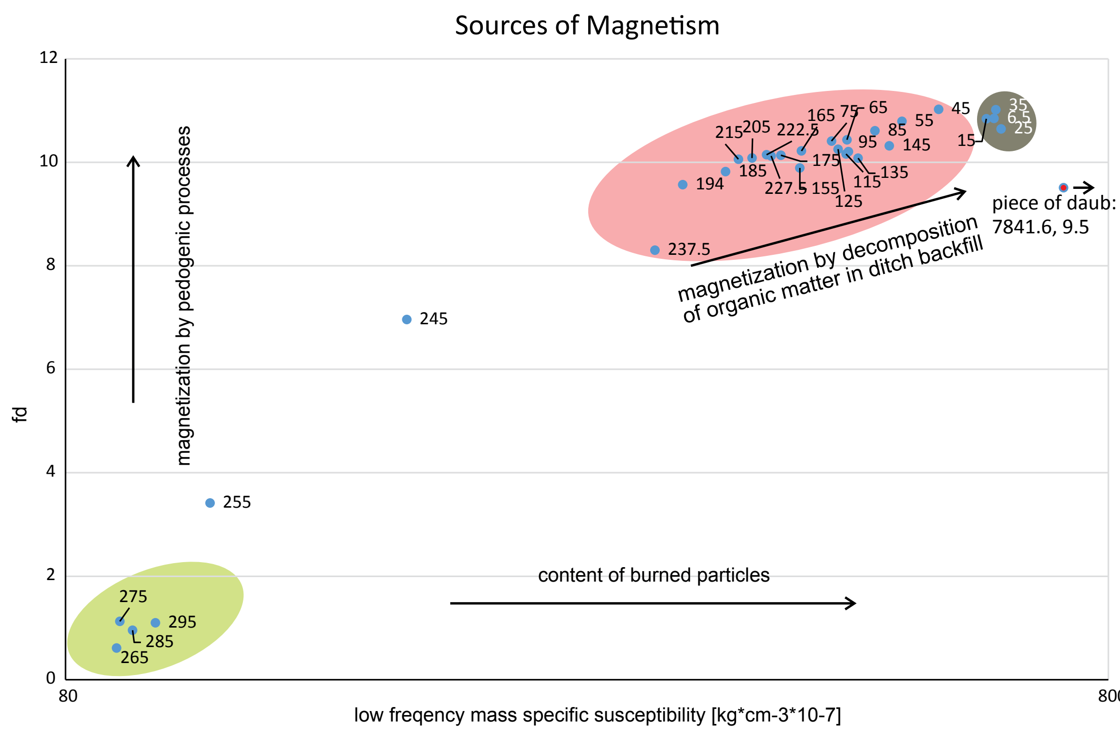


Figure 6. Borđoš, Core 1008. Principal components analysis, showing grouping of loess, backfill and surface soil (top) and magnetic susceptibility plot, illustrating the maintenance of magnetic enhancement by organic matter decomposition in the backfill (note the much higher value of a piece from the basal daub layer) (bottom, after Dearing 1999).

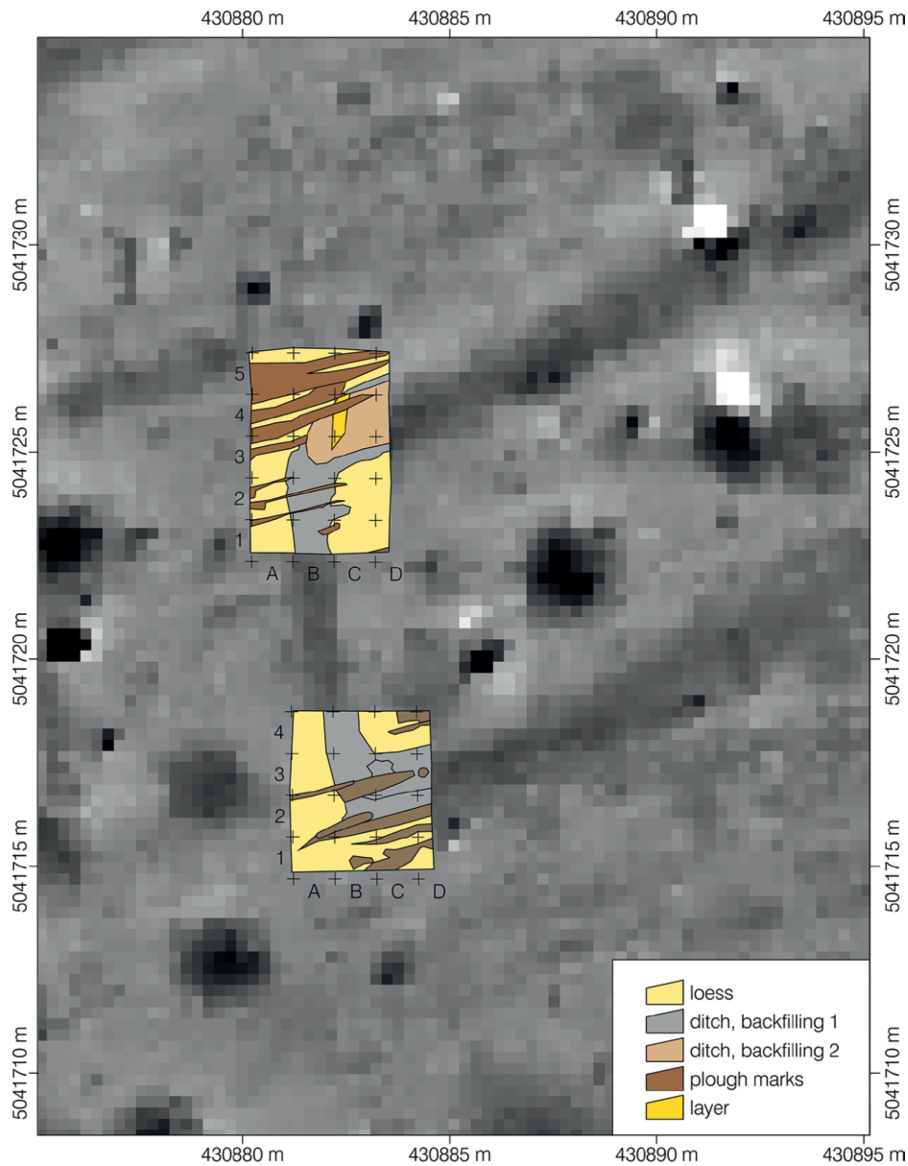


Figure 7. Borđoš. Magnetic map showing location of on the eastern flank of the southern entrance to the circular ditch and, superimposed, a plan view of the features of the first planum in Trenches 2 and 3 (after removal of the surface layers).

the termination of the Neolithic settlement. This backs the hypothesis of southern European chernozem formation by anecic earthworms that were fostered by prehistoric agriculture (Dreibrodt *et al.* 2022).

Excavations

In the southern part of the circular enclosure, two trenches measuring 3.5 × 4 m each (combined total area 28 m²) were excavated in summer 2014 (Fig. 2). These trenches were located in the area of the southern entrance to the enclosure, at the intersections of the interruptions of the ditch and the interconnecting ditch (Fig. 7). By integrating the connecting ditch into the investigation, it was possible to clarify the stratigraphic relationship between the two ditches.

In the area of the two trenches, the elevation of the terrain surface rises from 78.40 m to 78.85 m² in south-easterly direction (Fig. 8). After removal of a top layer of humus, with a thickness of 0.4 m, the upper edges of the ditches, both 1.6 m wide, became visible, as well as those of the connecting ditch, which was much narrower, with a width between 0.8 and 1 m.

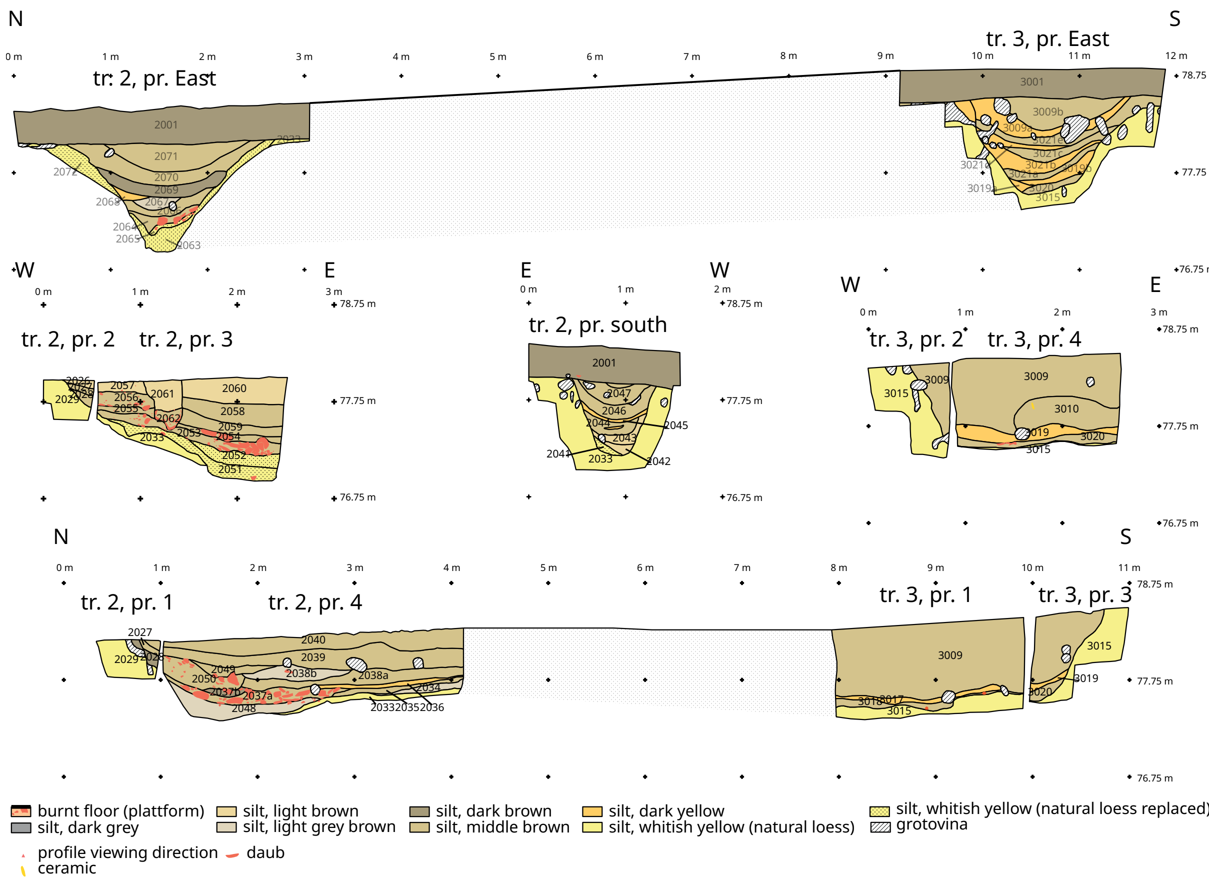


Figure 8. Borđoš, Trenches 2 and 3. Transverse and longitudinal profiles of Trenches 2 and 3 through the inner and outer ditches of the circular enclosure system and the connecting ditch. tr=Trench; pr.=profile.

Figure 9. Borđoš, Trench 2. Overhead photograph showing the accumulation of daub in the inner ditch.

	Trench 2		Trench 3	
Feature group	Features	Levels	Features	Levels
Topsoil	2001	1, 2	3001	1
Plough marks	2002-2007, 2011, 2012, 2014	2	3002-3008, 3013, 3014	2
Pit	2061, 2062			
Posthole			3012	
Upper ditch fill	2008, 2010, 2016, 2017, 2038-2040, 2044-2047, 2049, 2055-2060, 2069-2071	3, 4	3009-3011, 3021	2-5
Lower ditch fill	2018-2028, 2030-2037, 2041-2043, 2048, 2050-2054, 2063-2068, 2072	5, 6, 7	3016-3020	6
In-situ loess	2013, 2029, 2033	2-7	3015	

Table 1. Borđoš, Trenches 2 and 3. Assignment of features and levels to stratigraphic group.

The bottom of the ditch was reached at a level between 76.95 and 77.12 m in the inner ditch and at a level of 77.55 m in the outer ditch. At the bottom of the inner ditch, there is an approximately 0.2 m thick layer of yellow clay, which is probably the result of erosion from the ditch walls. In the outer ditch, such a layer seems to be missing.

While the inner ditch has a V-shaped cross-section, both the outer ditch and the connecting ditch have a U-shaped cross-section. However, the walls of the outer ditch have a fairly shallow slope, whereas the walls of the connecting ditch are almost vertical.

All of the ditch segments we excavated show more or less differentiated layers, resulting from repeated filling events or sub-events. In one of the earliest backfilling events, a large amount of daub was placed into the ditches from the interior space of the enclosure. Correspondingly, the daub is concentrated in the area of the inner ditch, where it forms a layer of about 0.2 m thickness (Fig. 9). The in part massive pieces of daub show imprints of logs and split-wood planks. Isolated pieces of daub are scattered over the entire length of the connecting ditch and can also be found in the lower backfill of the outer ditch. This seems to indicate that both ditches were both exposed and backfilled simultaneously.

In all of the excavated ditches, above the burnt construction debris (upper ditch fill), dark, humic layers alternate with thinner, yellow loessic layers. Some of the dark layers are strongly intermixed with yellow spots, while others are homogeneously humic halfway up the ditches, very dark, strongly humus-rich deposits are concentrated in both the inner and the outer ditch. For the moment it is unclear whether this humus layer is the result of soil formation and thus indicates a longer interruption of the backfilling process, or whether it is merely the result of inhomogeneity of the fill material being used. The latter scenario is supported by the absence of this humus layer in the connecting ditch.

Based on the differentiation of fill layers with remains of the burnt construction and the overlying layer package, a lower and an upper ditch fill can be distinguished. Further related feature groups of features are the topsoil, plough marks and the overlying loess (Table 1).

The bottom of the 0.4 m thick top layer above the ditches shows a sharp demarcation with the top of the ditch fill. To either side of the ditches, the top layer is sharply demarcated from the yellow loess. Thus, the layer above the ditches was most likely deposited by erosion in the post-Neolithic period. Accordingly, due to the location on the slope, neither the natural topsoil nor the ancient surface from the period of construction of the circular enclosure are preserved. This may explain why the internal space of the enclosure does not show any clear building structures.

	Trench 2		Trench 3	
Feature group(s)	n	Weight (g)	n	Weight (g)
Topsoil and plough marks	40	897	12	398
Upper fill	1	5	5	674
Lower fill	7	705	1	39

Table 2. Borđoš, Trenches 2 and 3. Amount and weight of pottery.

	Feature identifier							
Ware	2001	2023	2025	2030	2037	3001	3009	3010
Fine 1 and 2 (black and grey)	4	1		1		1	8	1
Coarse 1 (grog temper)	31	3		2	1	11	13	
Medium 1 (smoothed surface)	8	1	1			3	1	1
Medium 3 (organic temper)		1		1		1		1

Table 3. Borđoš, Trenches 2 and 3. Distribution of Neolithic pottery fabrics in features (n fragments).

In conclusion, through our excavations, we have been able to show that in the interior space of the circular enclosure at Borđoš, building structures must have existed, whose remains were largely destroyed by erosion. An exception may be parts that are dug into the ground, such as the investigated ditches. Because of differences in the quantity of loess-like deposits that have washed off the ditch walls and been deposited at the bottom of the ditch, it cannot be excluded at the moment that the ditches were dug one after another. However, the distribution of burnt debris in the lower backfill layers indicates that both ditches were exposed directly before they were abandoned and that they were backfilled simultaneously. The highly differentiated stratigraphies and the accumulations of humus at medium depth in both ditches may indicate that the backfilling process took place over a longer period of time or the intentional filling in of humus-rich topsoil from a source in the vicinity. To be able to opt between these scenarios, it is necessary to take a closer look at the ^{14}C and OSL dates.

Pottery

The total weight of the pottery found in the two excavation trenches is only about 2.7 kg (n fragments 107) and very low compared with other contexts at Borđoš (Table 2). Of this quantity, 1.3 kg, or 70 pieces, originate from the colluvial top layer, which is not part of the ditch backfill. In Trench 2, the largest amount of pottery was found associated with the daub from the interior space of the earthwork, while the layers above were relatively lacking in finds. In contrast, in Trench 3 the ceramics were relatively evenly distributed in the ditch backfill. Therefore, we can probably distinguish between (1) pottery that was dumped into the inner ditch together with the daub debris deriving from a destroyed building or other construction in the interior space of the rondel; and (2) pottery that was potentially deposited into the outer ditch from the outside.

From the macroscopic, technological point of view, it is possible to distinguish dark burnished black and grey fine fabrics, organic- or grog-tempered medium-fine fabrics and grog-tempered coarse fabrics (Table 3; note that post-Neolithic wheel-made pottery fabrics are excluded from this table). There is a certain tendency towards higher frequencies of fine fabrics in the upper fill of the outer ditch, which may be a further indication that the pottery from the lower and the upper ditch fills has different origins. The reconstructed morphological and decorative spectrum is shown in Fig. 10.

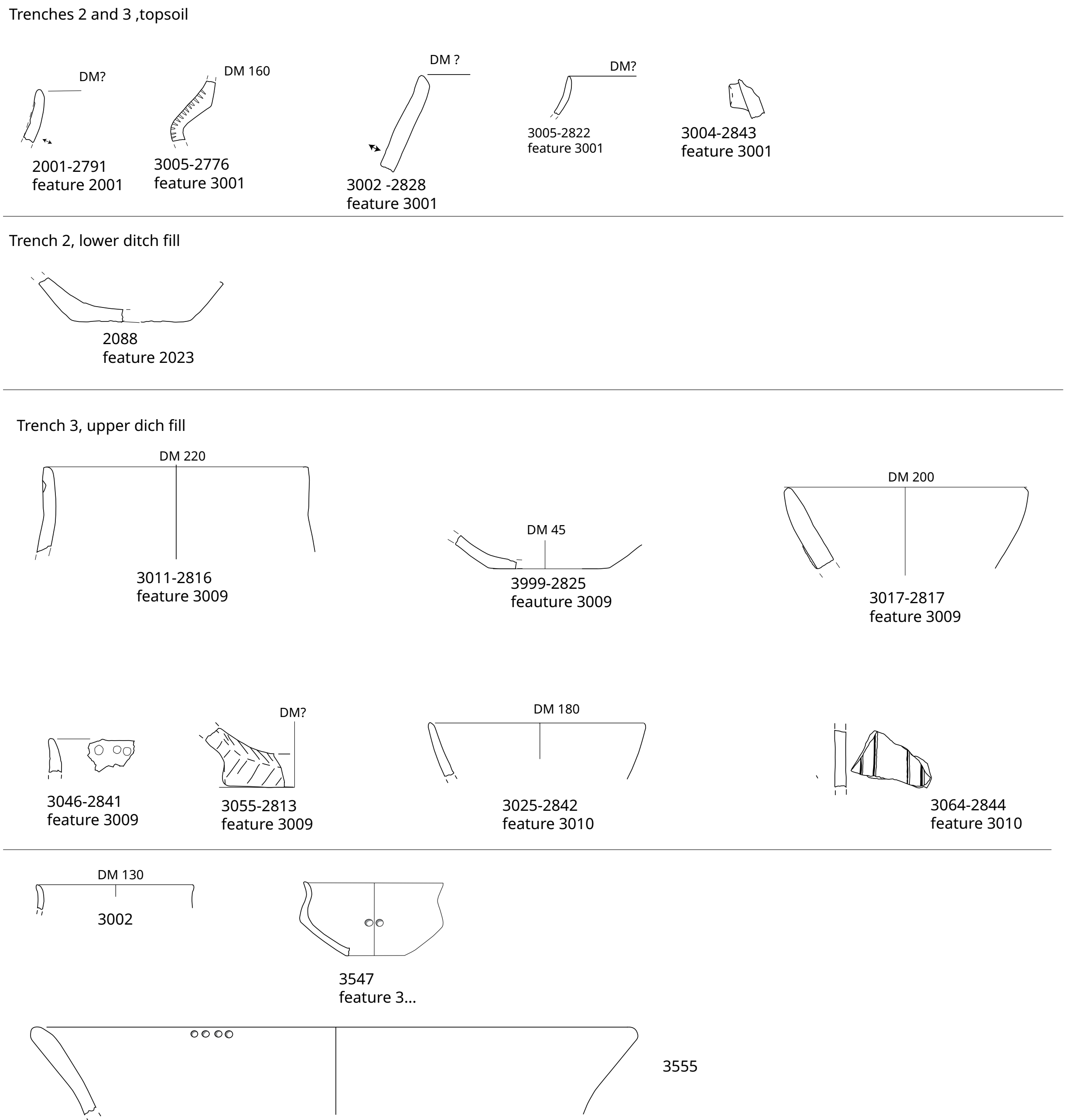


Figure 10. Borđoš, Trenches 2 and 3. Drawings of pottery from different stratigraphic groups.

Find identifier	Feature identifier	Level	n	Weight (g)	Flint material	Tool type
2032	2018	4	1	1.3	radiolarite	perforator
2032	2018	4	1	1.6	grey radiolarite (?)	borer
2032	2018	4	1	7	grey-honey yellow flint	side-scraper
2032	2018	4	1	15	radiolarite	rejuvenation flake

Table 4. Borđoš, Trenches 2 and 3. List of chipped stone artefacts with context information, raw material and tool type.

	lower fill				upper fill			all
Level	7	6	5	**sum**	4	3	**sum**	total
Number of analyzed soil samples per level	2	4	3		4	1	**5**	14
The total volume of soil samples in liters per level	9	9	11	**29**	22	5	**27**	56
Cereals								
Triticum monococcum	1			**1**	1		**1**	2
T. cf. *monococcum*			1	**1**				1
Triticum			1	**1**				1
Cerealia indeterminata	2	2	2	**6**	3	1	**4**	10
T. monococcum, spikelet forks	9	13	100	**122**	14		**14**	136
T. cf. *monococcum,* spikelet forks	3	79		**82**				82
T. timopheevii, spikelet forks	3	7		**10**				10
T. cf. *timopheevii,* spikelet forks	1	3	1	**5**	3		**3**	8
T. cf. *dicoccum,* spikelet forks		7		**7**	3		**3**	10
T. non-*monococcum,* spikelet forks			8	**8**	1		**1**	9
T. non-*monococcum,* terminal spikelet forks		1	8	**8**	1		**1**	10
Triticum, spikelet forks	3			**3**				3
Hordeum, rachis internodes			1	**1**				1
Gathered fruits and nuts								
Prunus	1		1	**2**	1		**1**	3
Prunus, endocarp/mesocarp			1	**1**				1
Fragaria vesca		2		**2**				2
Trapa natans					1		**1**	1
cf. *T. natans*					1		**1**	1
cf. *Cornus mas*		1		**1**				1
Synanthropic vegetation s.l.								
Chenopodium	4	26	26	**56**	5		**5**	61
Ch. album		16		**16**				16
Echinochloa crus-galli		10	6	**16**				16
Bromus		2	1	**3**	1		**1**	4
Fallopia convolvulus		2		**2**	2		**2**	4
Polycnemum cf. *arvense*						1	**1**	1
Setaria viridis/verticillata		1		**1**				1
Silene-type					1		**1**	1
Stipa, awn fragments	1			**1**				1
Poaceae	1	2		**3**				3
Solanaceae		1		**1**			**1**	1
Sum	**29**	**175**	**157**	**361**	**38**	**2**	**40**	401
Charred wood, pieces								
Quercus	12	270	29	**311**	16	3	**19**	330
Ulmus	3		1	**4**				4
cf. *Viburnum*		6		**6**				6
Diffuse-porous wood, deciduous tree		23		**23**				23

	lower fill				upper fill			all
Sum	**15**	**299**	**30**		**16**	**3**	**19**	363
Mineralized								
Sambucus ebulus			3	**3**				3
Sambucus			1	**1**	1		**1**	2
Number of analyzed hand-picked wood samples per level	2	11	8	**21**	14	5	**19**	40
The total volume of hand-picked wood samples in liters per level	1	5.5	4	**10.5**	7	7	**14**	24.5
Charred wood, pieces								
Quercus	53	198	231	**482**	104	19	**123**	605
Ulmus						1	**1**	1
Sum	**53**	**198**	**231**	**482**	**104**	**20**	**124**	606

Table 5. Borđoš, Trench 2. Macrofossil plant remains differentiated according to the depth (levels) of excavation and larger stratigraphic units (feature groups). Unless otherwise noted, the number of charred and mineralised seeds, and one-seeded fruits is given.

Chipped stone artefacts

Within Trenches 2 and 3, at least four chipped stone artefacts were found which have been disposed of from the interior space of the circular enclosure together with daub from a building or other structure (Table 4). Their very small number is probably due to the fact that at the beginning of our excavation, the excavated sediment was not yet being sieved. All specimens belong to the category retouch-modified tools.

Based on the petro-archaeological analysis, two pieces belong to radiolarite; one to grey radiolarite (?); and one to grey-honey yellow flint, which, most probably, is also a variety of the grey radiolarite. Morphological analysis of the findings was performed macroscopically according to the principle of parallel comparison with the available collections of lithological databases (http://www.ace.hu/litot/indexe.html and http://www.flintsource.net/index.html) and published lithic reference collections (Biró 2005). Radiolarite is the second most widespread raw material at the archaeological site of Borđoš. It has been detected in all excavated areas, and it most probably originates from Bakony Mountains, in western Hungary.

Botanical remains

The results of the macro-botanical analyses of samples from Trenches 2 and 3 can be summarised with the Scottish expression that many littles make much[1]. A total of 54 samples (both soil and hand-picked wood samples) from Trench 2 (Table 5) yielded 401 charred remains of the generative plant parts, while only 96 charred seeds or fruits and chaff fragments could be singled out from 37.5 litres of floated soil substrate from Trench 3 (Table 6). The number of identified charred wood parts was higher: 969 items from Trench 2 and 137 items from Trench 3. The samples were collected from several layers of both ditches.

The most abundant functional group in the botanical collection was cereals, followed by taxa of synanthropic vegetation in the broad sense and gathered fruits and nuts (Tables 5 and 6). Two thirds of all finds from Trench 2 belong to chaff, but just over half of all chaff fragments could be assigned to plant species – einkorn (*Triticum monococcum*) and Zanduri wheat[2] (*T. timopheevii*). Spikelet forks of Zanduri wheat are robust and strong, with a round and deep disarticulation scar and a prominent keel (Fig. 11.a) on the adaxial side (Kohler-Schneider 2003; Kenéz *et al.* 2014). In contrast to other glume wheat species, parallel and well-defined

1 'Mony a mickle maks a muckle'.
2 The allocation to this type of wheat is controversial; therefore many archaeobotanists still use the botanically inappropriate term new glume wheat or its acronym, NGW.

	lower fill	upper fill					
Level	6	5	4	3	2	**sum**	**total**
Number of analyzed soil samples per level		3	2	2	1	**8**	**8**
The total volume of soil samples in liters per level		11	5,5	3,5	6	**26**	**26**
Cereals							
Triticum aestivum s.l.					8	**8**	**8**
T. monococcum		1				**1**	**1**
T. cf. *dicoccum*		2				**2**	**2**
T. monococcum/dicoccum		1				**1**	**1**
Triticum		1				**1**	**1**
cf. *Hordeum*				1		**1**	**1**
Cerealia indeterminata		3	2	3	3	**11**	**11**
"Mash" fragments		24				**24**	**24**
T. monococcum, spikelet forks		3	2	1		**6**	**6**
T. timopheevii, spikelet forks		1	2			**3**	**3**
T. monococcum/timopheevii, spikelet forks		1				**1**	**1**
T. non-*monococcum,* spikelet forks		1				**1**	**1**
Triticum, spikelet forks		3	2		2	**7**	**7**
Hordeum, rachis internodes		1				**1**	**1**
Gathered fruits and nuts							
Prunus cf. *spinosa*		1				**1**	**1**
Prunus non-*spinosa*				1		**1**	**1**
Prunus		1	2		1	**4**	**4**
cf. *Trapa natans*		1			1	**1**	**2**
Synanthropic vegetation s.l.							
Stipa			1			**1**	**1**
Stipa, awn fragments		2	2	2		**6**	**6**
Chenopodium album			2			**2**	**2**
Chenopodium		2				**2**	**2**
Agrostemma githago					1	**1**	**1**
Bromus cf. *secalinus*		1				**1**	**1**
Solanum nigrum			1			**1**	**1**
Polygonaceae			1		2	**3**	**3**
Apiaceae				1		**1**	**1**
Poaceae, culm				1		**1**	**1**
Unidentified				1		**1**	**1**
Sum		**50**	**17**	**11**	**18**	**96**	**96**
Charred wood, pieces							
Quercus		6	3	9		**18**	**18**
Ulmus		3	9	2	1	**15**	**15**
Diffuse-porous wood, deciduous tree		1		1	3	**5**	**5**
Sum		**10**	**12**	**12**	**4**	**38**	**38**

	lower fill	upper fill					
Mineralized							
Sambucus ebulus		1	3		1	**5**	**5**
Number of analyzed hand-picked wood samples per level	5	5	4	2	7	**18**	**23**
The total volume of hand-picked wood samples in liters per level	2,5	2,5	2	1	3,5	**9**	**11,5**
Charred wood, pieces							
Quercus	1						**1**
Ulmus	15	24	9	24	21	**78**	**93**
Diffuse-porous wood, deciduous tree							
Ring-porous wood, deciduous tree					5	**5**	**5**
Sum	**16**	**24**	**9**	**24**	**26**	**83**	**99**

Table 6. Borđoš, Trench 3. Macrofossil plant remains differentiated according to the depth (levels) of excavation and larger stratigraphic units (feature groups). Unless otherwise noted, the number of charred and mineralised seeds, and one-seeded fruits is given.

*Figure 11. Borđoš, Trench 2. Charred chaff of Zanduri wheat (*Triticum timopheevii*), spikelet fork: a) adaxial view; b) abaxial view.*

veins are observable both on the single glume bases and on the whole spikelet forks in abaxial view, where it gives the impression of a 'raised collar' (Fig. 11.b). The poor preservation of chaff fragments is demonstrated by increased use of the abbreviation cf. and the prefix non- (not belonging to one but others) in the tables. One fragment of a spikelet fork could be categorised only as *T. monococcum/timopheevii*. Among the chaff remains, fragments of emmer spikelet forks (*T.* cf. *dicoccum*) and rachis internodes of barley (*Hordeum*) could be also singled out. There were only a few charred grains that could be determined (Tables 5 and 6). In most cases, the preservation of grain fragments was so poor that most finds were described as unidentified cereals.

Charred remains of einkorn and Zanduri wheat were found in the lowest layers of both ditches. These are also the most important cereals at two other Neolithic sites in the region, Uivar (Schier and Draşovean 2004) and Hódmezővásárhely-Gorzsa (Medović and Horváth 2012). On the map representing several emerging centres of 'new glume wheat' in central Europe, the record of Zanduri wheat from Borđoš is one of many dots in the south-eastern part of the Carpathian Basin (Kenéz *et al.* 2014).

The finds of carbonised grains and awn fragments of feather grass (*Stipa*) suggest that this plant could have had an important role in the life of the prehistoric settlers (Fig. 12). Awn fragments of *Stipa* were also found in a Late Neolithic house dated between about 5200 and 4840 cal BCE on the opposite side of the terrace, 2.5 km north-east of Borđoš (Medović 2019). Feather grass has been gathered and used from at least Neolithic times in central Europe (Bieniek and Pokorný 2005). Its grains were found in an Early Bronze Age storage pit in the Central Bohemian Lowland, in the Czech Republic. The grains are edible and the whole plant is useful for more than one purpose. Nowadays, spikelets of feather grass are used for decoration in

*Figure 12. Borđoš, Trench 3. Charred feather grass (*Stipa*) remains: a) grain fragment; b) awn fragments; c) cross-section of an awn.*

the region of South Banat. The grass is eaten by grazing livestock, but only in early spring, before the emergence of the feathery, flowering spikes, as these are sharp and can be dangerous to herbivores. Nevertheless, feather grass can only survive in places with minimum grazing pressure (Rühl *et al.* 2015). It is an indicator of open steppe grasslands.

Information on the forest vegetation in the Borđoš area is provided by the charred wood record presented in Tables 5 and 6. The majority of the hand-picked charred wood samples could be interpreted as timber used as building material in the settlement, implying a selection of wood for specific structural elements. Ditches at nearby Uivar were backed with palisades (Schier and Draşovean 2004). This could explain the predominance of strong, durable timber of oak (*Quercus*) and elm (*Ulmus*) among the wood charcoal in the ditches in Trenches 2 and 3. On the other hand, both oak and elm may have been the most common trees of the riparian forests along the River Tisza at the time and their presence in the trenches may simply reflect their natural abundance. In the forests of hardwood trees (*Ulmenion minoris*), which was liable to flooding during the regular rising of the water level, *Viburnum opulus* (guelder rose) occurs in the shrub layer. *Viburnum lantana* (wayfaring tree) prefers a zone not liable to flooding (Slavnić 1952). Our find of *Viburnum* could thus indicate either flooded or dry ground. In addition to the taxa represented by wood charcoal, a few more woodland species have been identified from Borđoš by their fruits, which were gathered by the inhabitants of the settlement. Cornelian cherry (*Cornus mas*) is a medium to large shrub or small tree that grows in dry areas at higher elevations. Several *Prunus* species can still be found growing on the edge of the terrace. Wild strawberries (*Fragaria vesca*) may have been collected in the forest clearings. Gathered fruits and nuts may also have been collected in the stagnant waters of the river. Today, water caltrop (*Trapa natans*), once a regular part of the diet of Neolithic people, can pose a nasty surprise to a careless swimmer in the Tisza, with its barbed spines. Rare are those who still gather the sweet-tasting nuts and roast them for food.

The functional group of synanthropic vegetation includes three vegetation types: weed vegetation of arable fields; ruderal vegetation of human settlements and their surroundings; and vegetation of the pastures, including natural grasslands, *e.g. Stipa.* The cornfield weeds identified from Borđoš are rye brome (*Bromus* cf. *secalinus*), other brome grass species (*Bromus*), and a climbing species – black bindweed (*Fallopia convolvulus*). Corn-cockle (*Agrostemma githago*) occurs together with bread wheat (*Triticum aestivum* s.l.) only in the uppermost of the excavated layers. Both finds from Trench 3 and the sole find of field needle-leaf (*Polycnemum* cf. *arvense*) from the upper layer of Trench 2 can be regarded as possible intrusions from the Bronze Age levels or later periods at Borđoš. The number of cockspur grass (*Echinochloa crus-galli*) finds is surprisingly high (Table 5, Fig. 13). It is one of the most numerous and frequent finds among the weed remains from the Late Neolithic site of Okolište, in Bosnia (Kroll 2013). This is a tall, robust, tufted, quick-growing annual grass that is cultivated in some parts of the world for grain (Heuzé *et al.* 2017). It can be grazed

*Figure 13. Borđoš, Trench 2. Charred caryopsis of cockspur grass (*Echinochloa crus-galli*): a) dorsal view; b) ventral view.*

before being harvested for grain. As a pasture species, though, it has fair to poor value for livestock. Today, it is considered one of the worst weeds worldwide. It is not possible to distinguish between charred seeds of green foxtail (*Setaria viridis*) and bristly foxtail (*S. verticilata*). But, new team members at Borđoš learn very quickly that the spikelike panicles of bristly foxtail hook easily onto socks and shoelaces.

The vegetation of waste ground is represented by the species that grow in the settlement itself, *e.g.* on refuse heaps and in unused corners, or outside the settlement. Its most prominent representatives in the Borđoš botanical collection are fat-hen (*Chenopodium album*) and other goosefoot species (*Chenopodium*). Other characteristic species are black nightshade (*Solanum nigrum*) and dwarf elder (*Sambucus ebulus*). The latter occurs only as mineralised seeds in the collection.

Zoological remains

Malacofauna

During the macro-botanical analysis of the samples, numerous 'small shells' were noticed and singled out. A subsample (Trench 2, level 4, upper ditch fill) was sent for analysis to Milica Radaković, Department of Geography, Tourism and Hotel Management, University of Novi Sad. Within this sample, 22 shell species were determined from a total of 831 (Table 7).

The majority of the malacological material indicates grassland or light forest environment (81.5% of the identified shells). Some shells indicate times when water filled the ditch and the environment became aquatic (11%) or periodically flooded (7.5%).

Additionally, nine molluscan fragments were separated out from the larger faunal assemblage by Sarah Pleuger. They were identified as mussel shells of the genus Unio (n=6) and gastropod shells, likely of the genus *Helix* (n=3).

Consequently, the molluscan fauna at Borđoš reflects mixed habitat types. Two major habitat types in the vicinity of Borđoš are aquatic and terrestrial. The existence of steppe and alluvial woodland, and of woodland on the Late Pleistocene Terrace, is also indicated.

Ichthyofauna

During the macro-botanical analysis of the samples, fragments of fish scales were noticed and separated out. Six subsamples, all from Trench 3, were sent for analyses to the Department of Biology and Ecology of the Faculty of Sciences, University of Novi Sad. Most of the fish scale fragments, 36, were found in the sample from the fourth

Species	Environment	Number of shells (MNI)	Percentage (%)
Anisus leucostoma	periodically flooded areas	63	7.6
Bathyomphalus contortus	permanent standing water	21	2.5
Bithynia leachii	slow-moving water	8	1
Carychium tridentatum	humid meadows	2	0.2
Cecilioides acicula	river deposits	1	0.1
Chondrula tridens	grassland	6	0.7
Clausilia pumila	forest	1	0.1
Cochlicopa lubrica	meadow/steppe	16	1.9
Columella edentula	alder swamps	1	0.1
Euconulus fulvus	meadow/forest/grassland	30	3.6
Granaria frumentum	grassland	1	0.1
Gyraulus albus	standing or slowly moving water	4	0.5
Physa fontinalis	standing or slowly moving water	1	0.1
Planorbis planorbis	standing or slowly moving water	42	5.1
Punctum pygmaeum	grassland	357	42.8
Pupilla muscorum	sand dunes/meadow/grassland	36	4.3
Pupilla triplicata	grassland	2	0.2
Succinella oblonga	wet open habitat/meadow	32	3.9
Theodoxsus fluviatilis	central and lower parts of rivers	2	0.2
Trochulus hispidus	light forest	157	19
Valonia costata	grassland	41	4.9
Valvata cristata	slow-moving water	7	0.8

Table 7. Borđoš, Trenches 2 and 3. Malacofauna.

excavation layer (Trench 3, upper ditch fill). Additionally, fish scales were found in the deepest part of both ditches (lower ditch fill). Unfortunately, they were not analysed.

Analysed fragments belong to species in the carp family (Cyprinidae). Characteristic of their cycloid scales is that they have a straight posterior (tail, or caudal) end and a more or less wavy anterior end, which is visible on the preserved fragments (Fig. 14). The fragments are mostly triangular presumably formed when the scale cracked along the primary radial grooves (Grginčević *et al.* 1987; Kostić and Maletin 1988). Most of the fragments are extremely solid. Some of them are slightly burnt. In the Carpathian Basin, the family Cyprinidae is the richest family in terms of number of species.

Ten fish bone fragments were recovered from the trowel-excavated faunal material from Trenches 2 and 3 by Sarah Pleuger. A total of 9 fragments originated from the upper backfill and 1 from the lower backfill; 5 of the 10, all from the upper backfill, could not be further identified to skeletal element or taxon, due to their fragmentary state. The remaining five were identified as *Esox lucius*, northern pike (n=4; cleithrum, parasphenoid, dentary and prehaemal vertebra), all from the upper backfill and *Cyprinus carpio*, common carp (n=1; pharyngeal), from the lower backfill. This latter find is consistent with the identification of fish scales as Cyprinidae.

Terrestrial faunal remains

A rather small (NISP=94) but well-preserved assemblage of faunal remains was obtained from excavation Trenches 2 and 3. With the exception of six specimen, most of the osteological material did not exhibit advanced stages of weathering (*e.g.* Behrensmeyer 1978), which would suggest that the majority of the bone remains

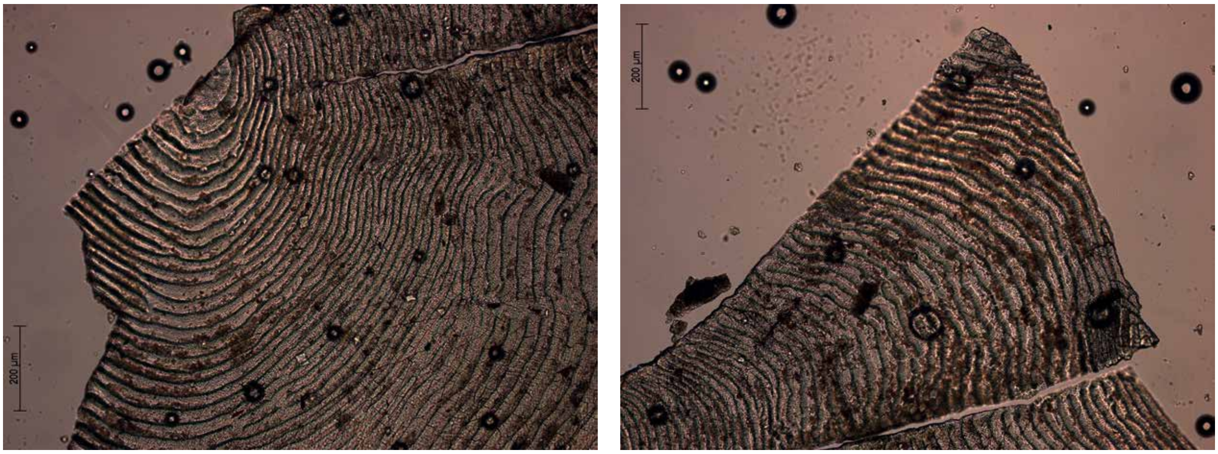


Figure 14. Borđoš, Trench 3. Fragment of a Cyprinidae fish scale, age 3+.

were not exposed at the surface for longer than around 2 years after defleshing and before being deposited into the ditches. Two fragments showed chewing marks by carnivores, which supports the idea that the material was probably not overly accessible on the surface before its deposition in the ditch. The small faunal bone assemblage from Trenches 2 and 3 demonstrates a subsistence based on domestic livestock herding complemented by the exploitation of wild resources (Table 8). The majority of bone specimens could not be further identified than to the level of large mammal (n=28), which corresponds with the size of *e.g.* cattle or horse; medium-sized mammal (n=2), which corresponds with the size of *e.g.* a sheep, goat, pig or dog; and either large or medium-sized mammal (n=21).

Identified mammalian bone specimens were mostly of *Bos* sp. (n=18). The only other mammal bones were identified as *Lepus* sp. (n=1) and a rodent roughly the size of a muskrat (n=1), which are potentially intrusive. Three bone specimens were identified as reptilian – two fragments (scapula and carapace) could be further identified as Testudinidae, most likely *Emys orbicularis* (European pond turtle).

All fragments identified as *Bos* sp. could have belonged to one or two individuals, based on present skeletal elements and considerations regarding elements with information on biological age. Six of the specimens were teeth, of which a single mandibular M/2 and M/3, respectively, could be aged based on tooth wear stages (Grant 1982; Legge 1992). The age for the M/2 can be estimated at 6-15 months and for the M/3 at 26-36 months. However, age estimations based on single teeth are not as reliable as fully preserved mandibles. The differential tooth abrasion might be the result of factors unrelated to biological age, such as malocclusion of the teeth or other pathologies, which we cannot exclude without evaluating a larger portion of the jaw. Skeletal elements other than teeth identified as *Bos* sp. belong to various body parts: the cranium and the mandibula, the axial skeleton, and the extremities.

Bone specimens that have been identified only to the level of large mammal (in this case probably also cattle) belong mostly to the categories of long bone shafts; ribs; and planar bones, such as scapula or pelvis, which are generally identifiable to skeletal element based on morphology or structure but lack diagnostic features for taxonomic identification. The undetermined long bone shaft fragments still bear some information, even though for a robust study a much larger data set would be necessary. Fracture patterns (after Outram 2001) have been recorded for indications regarding causes of the fractures. Of the respective fragments, 5 of 12 exhibited fresh fractures probably related to food processing; 4 of 12 showed dry fractures, which occurred sometime after deposition; and 3 of 12 showed both fresh and dry fracture patterns. We are probably looking at deposited food waste, part of which may have been relocated. Two bone fragments, a large mammal rib and

context	taxon	cranium	mandibula	tooth	vertebra	costa	pelvis	scapula	radius	astragalus	calcaneus	metapodial	metacarpal	ph2	ph3	long bone	indet	total
trench 2 topsoil	*Bos* sp.			2						1				1				4
	large mammal				1											1		2
	indet.																2	2
trench 2 lower fill	*Bos* sp.							1			1		1					3
	large mammal					2										1		3
	medium/large mammal							1										1
trench 3 topsoil	*Bos* sp.		1	1														2
	large mammal															3		3
	Lepus europaeus											1						1
	medium mammal															1		1
	medium/large mammal																1	1
trench 3 plough track	*Bos* sp.	1																1
	large mammal						1											1
trench 3 upper fill	*Bos* sp.	2		3	2										1			8
	carnivore?		1															
	large mammal	1			1	6		2								7	2	19
	medium mammal								1									1
	medium/large mammal															1	5	7
	indet.	1															6	7
	total	5	2	6	4	8	1	4	1	1	1	1	1	1	1	14	16	67

Table 8. Borđoš, Trenches 2 and 3. Taxa and elements of animal remains, by major feature groups.

vertebra, exhibited cut marks probably related to slaughtering. An indetermined bone fragment exhibited some use wear on one of the fracture surfaces and may have been used as an improvised tool of some sort. With a larger sample size of bone, a more detailed insight into taphonomic processes and antropogenic impact would be possible.

^{14}C dating

From drilling core BP1008, which was located at the centre of the longitudinal axis of the ditch, three dates on charcoal of unspecified taxa were obtained (Table 9). Samples Poz-63490 and Poz-63491 were taken from the lower section of the ditch, while sample Poz-63488 originates from a higher section. Unfortunately, all three dates show a very high standard deviation and correspondingly large dating ranges. Backfilling of the ditches started with the highest probability around 6600 BCE and with 95% probability before 6200 BCE. The much younger date from higher levels suggests an extremely long process of backfilling, which was most likely completed around 5000 BCE.

The suggested early beginning of the ditches, in the 7th or 8th millennium BCE, cannot be confirmed through the widely consistent series of dates from the excavation trenches (Table 9). According to a first model, in which the beginning and the end of

laboratory-id	^{14}c date	sample material	taxon	sample material details	N (%)	C (%)	col (%)	trench-id	find-id	feature-id	level	x	y	context
Poz-63488	6110 ± 90	charcoal	indet.	drilling core BP1008 -158 cm				1	1195					circular earthwork, backfilling ditch
Poz-63490	7690 ± 100	charcoal	indet.	drilling core BP1008 -234 cm				1	1197					circular earthwork, base ditch
Poz-63491	7260 ± 180	charcoal	indet.	drilling core BP1008 -246 cm				1	1198					circular earthwork, base ditch
Poz-90469	6055 ± 35	bone	cattle	part skull	1,8	7,1	3,1	3	3066	3009	2	C	3	circular earthwork, area 2, backfilling ditch, above daub layer
Poz-90470	6110 ± 40	bone	cattle	tibia, distal, left	1,2	6	5	3	3035	3009	3	D	2	circular earthwork, area 2, backfilling ditch, above daub layer
Poz-90471	6115 ± 35	bone	cattle	scapula, right side	0,9	4,7	2,5	2	2091	2023	6	C	3	circular earthwork, area 2, backfilling ditch, layer with daub
Poz-90472	6100 ± 40	seed	*Triticum* sp., *Triticum* cf.					2	2053	2023	5	B	3	circular earthwork, area 2, backfilling ditch, layer with daub
Poz-90473	6020 ± 40	bone	cattle	young, molar m1 or m2	0,8	4,5	2	2	2107	2030	7	C	4	circular earthwork, area 2, backfilling ditch, below daub
Poz-90475	6110 ± 40	seed	*Prunus*	4 mg				2	2104	2030	7	B	3	circular earthwork, area 2, backfilling ditch, below daub

Table 9. Borđoš, circular enclosure. List of ^{14}C dates from drilling cores and excavations.

the backfilling process were modelled without further stratigraphic differentiation, the highest dating probability range falls in the period between 5025 and 4950 BCE or between 5067 and 4927 BCE in the 68.2% probability range (Amodel 112). A second model takes into consideration the stratigraphic distribution of the dates below and above the daub from the destroyed architecture situated in the interior space of the rondel. In that case, the dating range can be narrowed down, to the period between 5025 and 5020-5000 BCE with the highest probability or between 5050 and 4943 with 68.2% probability (Amodel 77.5%). Thus, a very short period of backfilling of the ditches, in the range of 5-35 years, should be taken into consideration as a possibility, although longer-term abandonment processes cannot be excluded due to the relatively large calibration error.

Luminescence dating

The fine-grained quartz extracts used for OSL dating performed well on tests focusing on measurement reproducibility and the appropriateness of the applied SAR procedure. In terms of combined preheat and dose-recovery tests, a stable plateau with values close to unity could be identified concerning recycling and dose-recovery ratios mostly in the range of 180-260 °C (Fig. 15). OSL intensities in response of zero dose were usually less than 0.5% of natural intensities, referring to a negligible charge transfer as a result of heating. In general, a 220 °C preheat temperature was found to be optimal for the SAR measurements, whereas cut heat was kept uniformly at 160 °C.

Measurement reproducibility, assessed by a more extensive dose-recovery test on naturally bleached aliquot and using the SAR settings tuned during preheat tests also proved the robustness of the applied procedures and the selected preheat

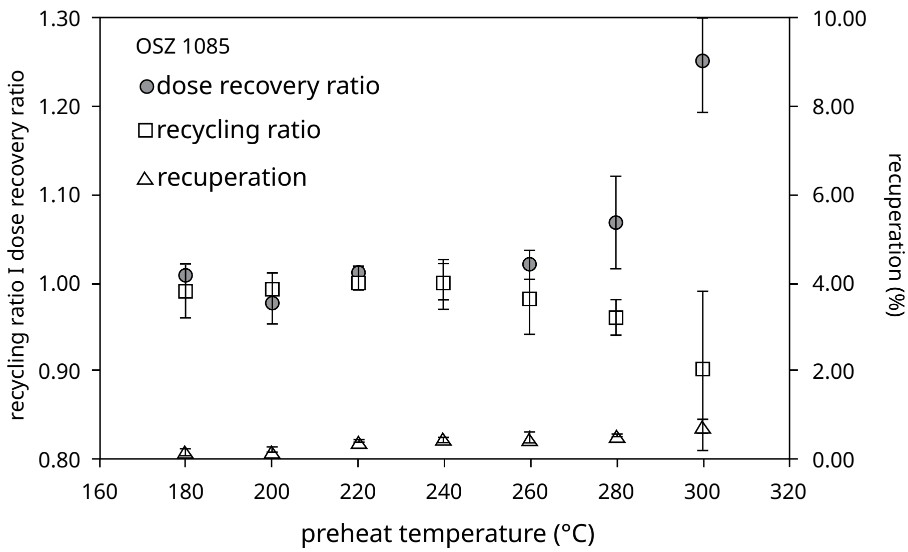


Figure 15. Borđoš, sample OSZ 1085. OSL results of combined preheat and dose-recovery tests. Each value is the mean of three measurements; error bars represent the standard deviation of the results.

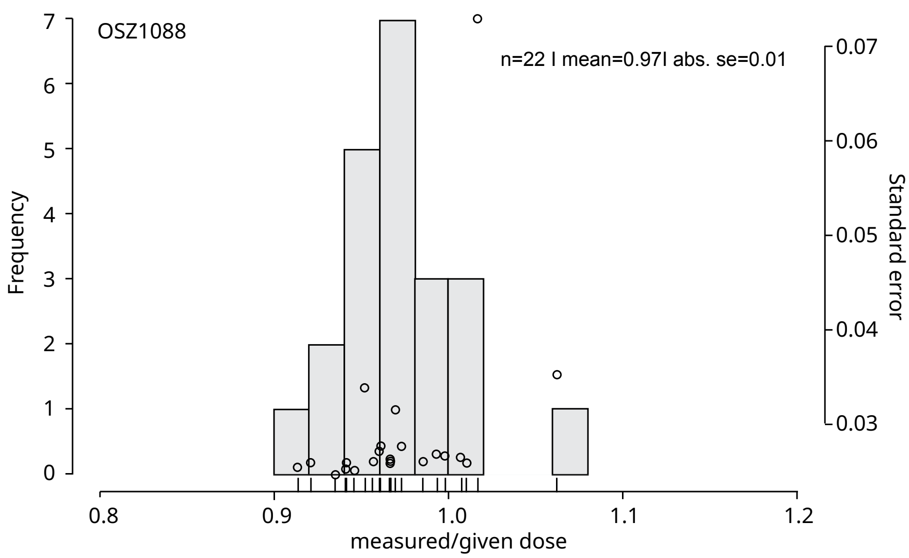


Figure 16. Borđoš. The distribution and standard error of measured/given dose values, determined as part of a dose-recovery test.

temperatures. Known doses could be recovered at a relatively high precision (Fig. 16), meaning that unknown palaeo-doses absorbed since the deposition can be measured reliably, unless the measured doses are not affected significantly by residual doses as a matter of incomplete bleaching. Although a slight undershooting of the value of unity was experienced in terms of sample mean dose-recovery ratios (2-3%), results were well within the acceptable (10%) threshold of the test (Murray and Wintle 2003).

As expected, the distribution of De values in terms of the investigated fine-grained quartz samples showed a negligible scatter. The highest relative overdispersion (OD) value was experienced in the case of OSZ 1085, but it still only reached 4.5% (Fig. 17). The measured De values in terms of samples taken from the ditch were very similar, just like dose-rate values; thus the ages received for the ditch fill fell close to each other (Table 10). Although age inversion with depth can be recognised in two cases, mostly because of bioturbation proved by the presence of krotovinas, the results are practically within their error limits. Overlapping ages mean either that the samples represent the same deposition event or that the gradual filling up was quite fast. The mean age and standard error of ages measured from the ditch was calculated to be 8.45±0.14 ka, implying that silting up could have occurred in only a matter of a few centuries. In any of the cases mentioned above, there is a clear chance of age

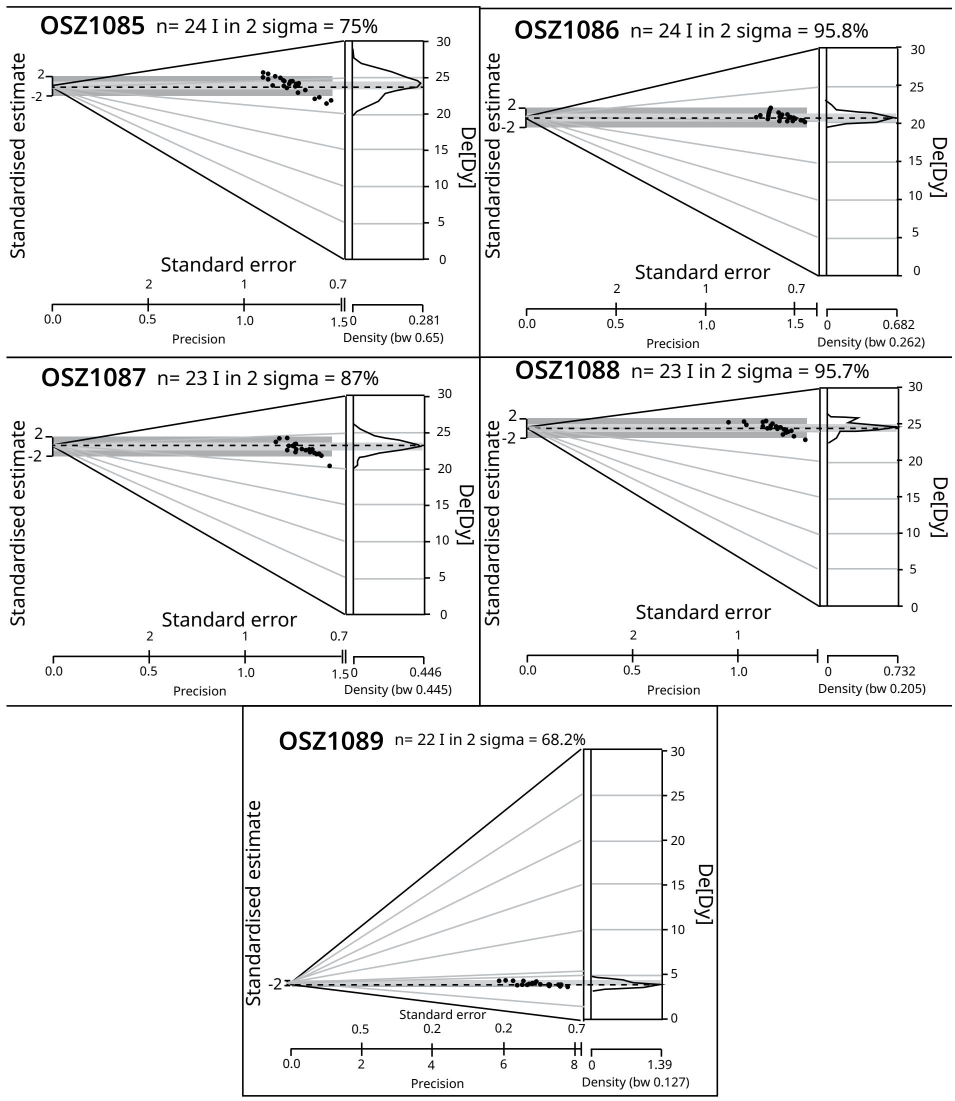


Figure 17. Borđoš. Abanico plots showing the distribution of equivalent doses for each sample.

Field identifier	Lab identifier	Depth (cm)	w1 (%)	U (ppm)	Th (ppm)	K (%)	D*2 (Gy/ka)	De3 (Gy)	Age (ka)
Borđoš LUM 0.75	1086	75 from top of ditch	17.4±5.0	3.33±0.14	7.70±0.56	1.47±0.08	2.59±0.09	21.11±0.34	8.14±0.31
Borđoš LUM 0.50	1088	50 from top of ditch	15.9±5.0	3.51±0.14	8.05±0.59	1.60±0.09	2.81±0.09	24.64±0.41	8.78±0.33
Borđoš LUM 0.15	1085	15 from top of ditch	8.5±5.0	3.31±0.14	8.09±0.59	1.46±0.08	2.89±0.10	23.96±0.46	8.30±0.33
Borđoš LUM 0.05	1087	5 from top of ditch	13.0±5.0	3.37±0.14	6.64±0.49	1.42±0.08	2.68±0.09	22.99±0.40	8.57±0.33
Borđoš LUM -0.35	1089	35 from topography	16.4±5.0	3.41±0.14	8.00±0.59	1.49±0.08	3.12±0.13	4.06±0.09	1.30±0.06

Table 10. Borđoš. OSL ages of samples and the data used for age calculation. 1=in-situ water content; 2=environmental dose rate; 3=equivalent dose.

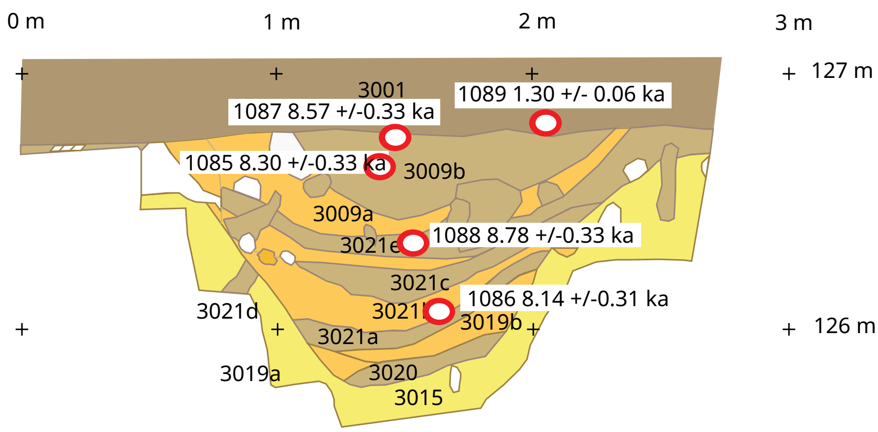


Figure 18. Borđoš, sou… entrance of the circul… Litho- and pedo-strati… of the connection ditc… luminescence samplin… and preferred ages.

overestimation as a result of potential residual doses. Consequently, the true age of the ditch fill may be less than the one inferred on the basis of luminescence dating.

The uppermost sample (1089), collected from above an erosion surface, was much younger (1.30±0.06 ka) than the samples below it (Fig. 18). This sample is also different in terms of its dose rate. Sample 1088, taken at 50 cm depth, shows greater age (8.78±0.33 ka) than the underlying sample 1086 (8.14±0.31 ka), taken at 75 cm depth. Sample 1085 lies at 15 cm bellow the top of the ditch part of the section yet yielded an age (8.30±0.33 ka) that is slightly older than that of the overlying sample 1087 (8.57±0.30 ka). These differences in OSL ages are most likely a consequence of intensive bioturbation by numerous krotovinas.

Additionally, the presented luminescence dates indicate a relatively short period for the filling in and covering of the ditch. The difference between the maximum and minimum luminescence ages is 640 a. Several episodes of initial pedogenesis are observed associated with numerous krotovina channels. Traces of intensive bioturbations are visible in all parts of the analysed buried ditch (Fig. 18). The luminescence dates confirm the conclusion drawn from the characteristics of the features that the topmost part of the of analysed ditch profile represents an erosional layer and that it is significantly younger (1.30±0.06ka) than the ditch fill. This layer represents an Ah horizon with a bit more clay content than a typical chernozem, developed on the gentle slope.

Discussion

The results of our interdisciplinary analyses allow us to make statements in response to several of the questions raised at the beginning of this paper.

Dating and assessment of the enclosure system

The ^{14}C and luminescence dating from the Borđoš rondel provide partly contradictory results, insofar as both series contain older than expected dates. The appraisal of these data requires consideration of the local and regional context.

1. Dating of the Neolithic in the study area: Although the find inventories described above do not, strictly speaking, represent the period of ditch use, but, rather, the time when the circular enclosure of Borđoš was already abandoned, we are clearly dealing with a Neolithic monument built in the context of an agrarian society. This assumption is supported by, among other things, the presence of pottery and cereal remains that are unknown from Mesolithic contexts. For the

dating of the beginning of the south-east European Neolithic, a comprehensive set of ^{14}C dates is available (*e.g.* Breunig 1987; Biagi *et al.* 2005; Whittle 2007; Bánffy *et al.* 2016; Tasić *et al.* 2016; Whittle *et al.* 2016; Meadows 2019; Porčić 2020). In the study area, the Early Neolithic is characterised by pottery in the Starčevo style, whose presence on sites started around 6100 BCE and ended circa 5400 BCE. From the perspective of these dates, the early dating of the rondel to the middle and second half of the 7th millennium, suggested by the early ^{14}C and luminescence dates, seems extremely unlikely. In the second half of the 6th millennium BCE, Middle and Late Neolithic inventories of the study region are characterised by Vinča, Tisza, Banat and Szakálhát pottery styles (*e.g.* Lazarovici 1979; Falkenstein 1998; Dammers *et al.* 2014). Since the ceramic material from the ditches is, unfortunately, undiagnostic, it is not possible to confirm whether it is Late Neolithic, as would be suggested by the majority of the ^{14}C dates.

2. Local settlement history: Considering the settlement history of Borđoš, which was just recently reconstructed based on 30 ^{14}C dates, a very early dating of the rondel in the 7th millennium does not seem plausible. According to our current data interpretation, the circular enclosure was in use simultaneously with the earliest layers of the adjacent tell settlement and may not have represented a place for living, but, rather, an area with special ritual (integrative) or economic functions (Hofmann *et al.* 2019). An early dating of the circular enclosure, to the 7th millennium, would raise the question of what functions such a facility may have had at that date, since there are no analogies at that date in the region so far. That the final abandonment of the circular enclosure occurred around 5000 BCE is, in contrast, relatively clear in the light of the ^{14}C dates. Only a short time afterwards, around 4900/4850 BCE, the location was overbuilt by a large flat settlement those ditches run also in the area of the former rondel. The early radiocarbon ages from samples taken at the base of the backfill in core 1008 may, instead, give hints to the environmental conditions at the start of the Neolithic settlement. Their early dating to around 1300 years prior to the Neolithic occupation of the Borđoš settlement may reflect the presence of pristine early Holocene woods in the surrounding of Borđoš at the time of Neolithic settlement.

3. Dating in light of other circular enclosure systems: Several recent studies deal with the phenomenon of circular enclosures or rondels and its chronology (*e.g.* Petrasch 1990; Literski and Nebelsick 2012; Raczky and Anders 2012; Řídký *et al.* 2019; Vondrovský *et al.* 2022). It is important to stress that proto-typical rondels occur usually within or next to settlements and are characterised by a circular ground plan; one to five parallel ditches; and regularly arranged entrances, frequently on two or four sides. Usually such enclosures are assumed to have emerged around 4900 BCE, associated with cultural groups such as Lengyel, Moravian-Austrian Painted ware, Southeast Bavarian Middle Neolithic (SOB), Hinkelstein, Großgartach, Stroke-Ornamented ware and Rössen (*e.g.* Meyer and Raetzel-Fabian 2006; Řídký *et al.* 2019) (Fig. 19). The end of the primary use of many rondels is ^{14}C dated between 4800 and 4700 BCE (Limburský *et al.* 2019), although some enclosures were in use much longer, until about 4500 BCE (*e.g.* Raczky *et al.* 2015).

Apart from these proto-typical cases, earlier ditch systems from the time around or before 5000 BCE existed in the context of the Linearbandkeramik (LBK) (*e.g.* Lüning 1988; Meyer and Raetzel-Fabian 2006), in eastern Hungary in the context of the Alföld LBK (Raczky and Anders 2012), and in the Balkans (*e.g.* Schier and Draşovean 2004; Hofmann 2013; Müller *et al.* 2013; Borić *et al.* 2018). However, these cases frequently show only some of the above-mentioned characteristics, and

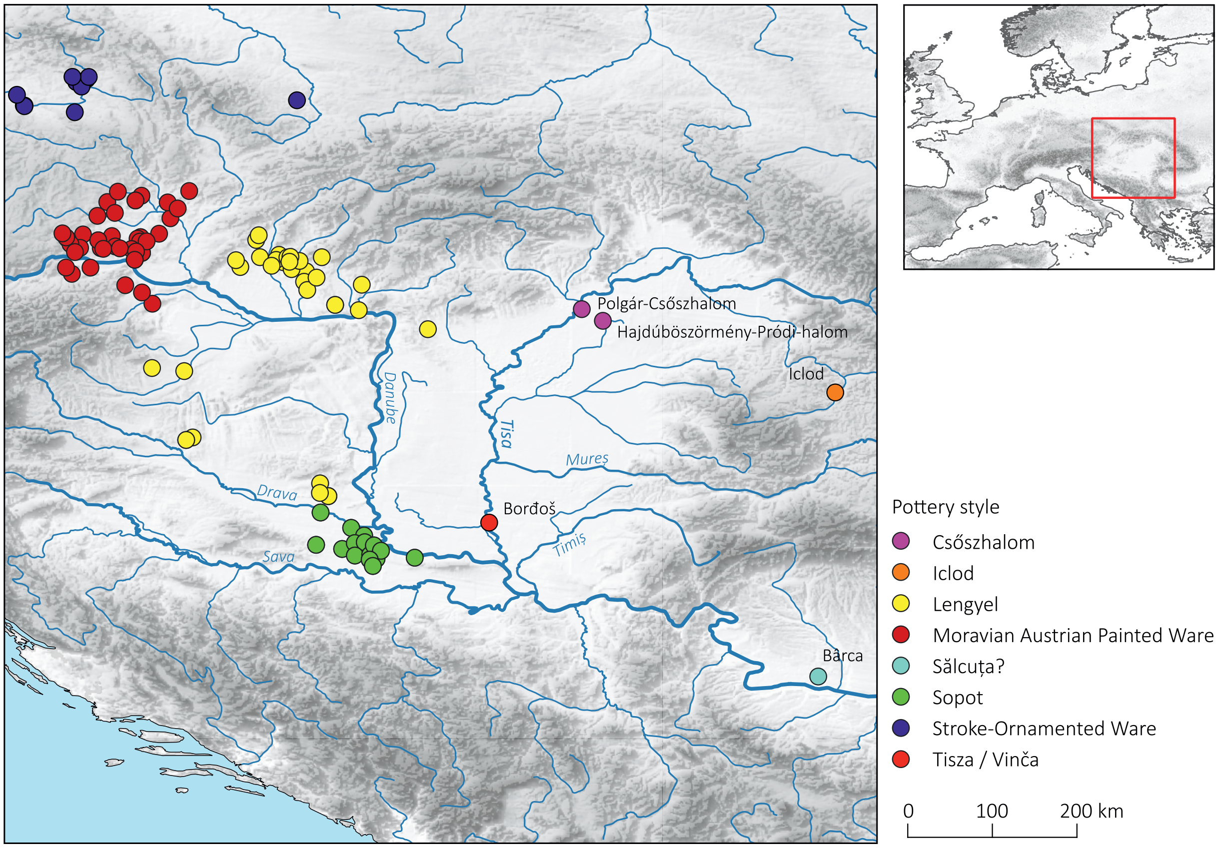


Figure 19. Map showing the spatial distribution of circular enclosures and related enclosures on the Pannonian Plain and in adjacent regions, by pottery style (sources: Lazarovici 2013; Raczky et al. 2010, 2011; Kalafatić and Šiljeg 2018; Řídký et al. 2019).

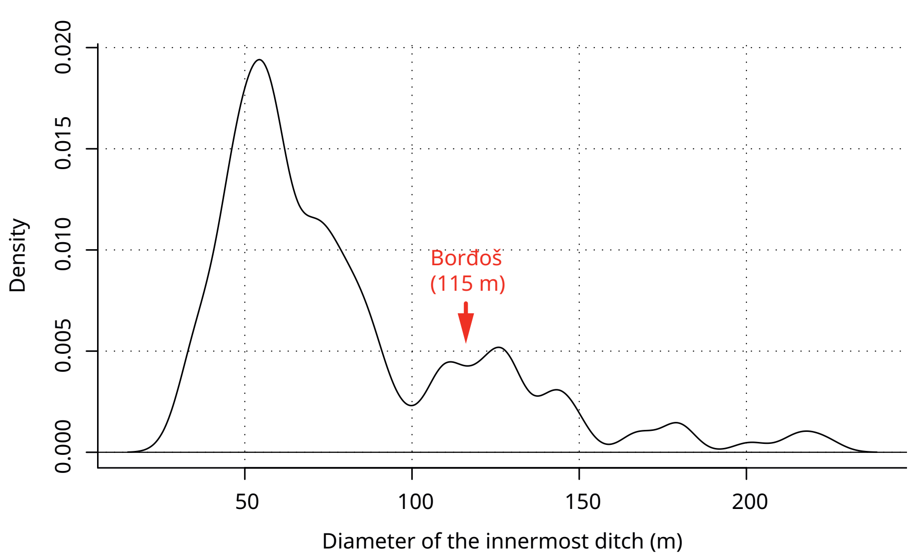


Figure 20. Diameters of the innermost ditches of European circular enclosure systems, displayed in a kernel density distribution with a bandwidth of 5 (sources: Raczky et al. 2010, 2011; Kalafatić and Šiljeg 2018, 77-109; Řídký et al. 2019, Table 4).

the clear distinction between ordinary settlements and spatially separated circular ditch systems cannot be made, especially in only partly investigated sites.

In some respects comparable to the rondel at Borđoš is the well-researched circular enclosure and settlement of Polgár-Csőszhalom, in the Upper Tisza region, which shows five rings of ditches, four gates facing each other on different sides, and a building with possible special integrative functions (*e.g.* Raczky and Anders 2008; Raczky and Sebők 2014; Raczky 2018). However, Bayesian modelling of ^{14}C dates indicates that the use of this enclosure started at the earliest around 4920 BCE, synchronously with the surrounding flat settlement, and that it was in use much

longer than the rondel from Borđoš, namely until about 4500/4450 BCE (Raczky *et al.* 2015).

A macro-regional comparison shows that rondels with two parallel ditches are one of the most common variants and that their distribution is not restricted to a specific region within the distribution areas of the rondels. More specific is the type of gate with interconnecting ditches (Type 24 following Řídký 2019), for which two analogies exist, at the Lengyel sites of Bajtava and Svodín 2, in Slovakia. Currently difficult to assess is the above-average size of the Borđoš circular enclosure, which, with an enclosed space with a diameter of 115 m belongs to the large examples (Řídký 2019) (Fig. 20).

From the perspective of the different pieces of evidence discussed above, the backfilling of the ditches of the Borđoš circular enclosure system was most likely carried out around or slightly before 5000 BCE. We consider the timing suggested by the ^{14}C and luminescence dates, namely that the filling process began in the second half of the 7th millennium BCE, to be very unlikely. In our opinion, other factors, such as old wood effects and the incomplete bleaching of the investigated sediments must be responsible for some dates. An explanation for the irregular increase in the OSL ages from the base to the top of the ditch can be found in intensive bioturbation activity, as indicated by the presence of numerous krotovinas. The circular enclosure at Borđoš nevertheless seems to be one of the earliest rondels spatially separated from an associated settlement, not only in the Tisza Valley but on the entire Pannonian Plain.

Functional and depositional aspects of the circular enclosure

The backfilling of the two ditches of the Borđoš circular enclosure occurred simultaneously and in a relatively short time, around 5000 BCE, according to the stratigraphy and scientific dating. Some significantly older ^{14}C and luminescence dates were discarded after source-critical and contextual considerations. We assume old wood effects to be the reason for the high age of two ^{14}C dates from the bottom of the ditch. We assume incomplete lighting as the cause of the high age for the luminescence dates. This incomplete lighting might indicate intentional and rapid backfilling, in which larger chunks of earth were excavated nearby and directly tossed into the ditch.

Our stratigraphic analysis also shows that the ditches of the circular enclosure were probably intentionally backfilled in their entirety. Differences in the characteristics and contents of the backfill layers indicate that the backfilling took place in at least two episodes. During these backfilling episodes, the destructors used earth material from different sources. From the interior space of the circular enclosure, they took parts of a burnt construction mixed with pottery and chipped stone artefacts and placed it in the ditch as the lowest backfilling. These materials we can functionally assign to the circular enclosure. The daub reveals that some kind of building or other construction probably existed inside the enclosure.

Above this daub layer, humus-rich deposits alternated with thin, yellow loessic layers. A massive humus layer mid-way the fill, which, based on the narrow time interval of the ^{14}C dates, is probably the result of the infilling of humus-rich material and not the consequence of a longer interruption of the filling process with associated soil formation. The condition of the majority of the animal bones speak against a scenario in which they were exposed on the surface for a longer period of time. The low finds density and even distribution of archaeological materials in these upper layers may indicate their infilling from outside of the circular enclosure. Consequently, these upper backfill layers do not need to have anything to do with the circular enclosure in a functional sense but may represent foreign waste. Also not related to the circular enclosure is the top layer above the ditches.

The sharp boundary between this layer and the underlying strata, together with its significantly younger luminescence dating, indicates that it represents a colluvium. Since the circular enclosure is located on a slope, it is unclear in how far the material from this colluvium and the surface finds are related to the circular enclosure.

In contrast, the finds which can be associated with the building or construction remains of the circular enclosure probably represent secondary waste and includes some pottery and some flint artefacts. The low quantity (pottery) and processing status (chipped stone artefacts) of this material places limits on our ability to draw conclusions about the range of activities carried out. The different qualities of fine, medium and coarse ceramic fabrics testify to a wide spectrum of activities, including the preparation, transportation and serving of food. However, the assemblage does not show a dominance of any of these activities. No reliable statements can be made about the use of the flint artefacts without use-wear analyses.

Differences in the density of finds and the composition of plant remain assemblages between the lower and upper backfill layers and the cover layers confirm the infilling from different sources in different filling episodes.

From a zooarchaeological perspective, only a very small number of bones (3 of 12) exhibited mixed fracture patterns that can be linked to potential re-deposition of remains. However, the sample size is too small to allow us to test whether this is statistically meaningful. Analysis on a larger sample from the contexts could certainly help to further investigate the depositional history.

The find assemblages presented in this article are, in the end, relatively unspecific with respect to indicating possible functions of the circular enclosure. The special character of the enclosure, however, be deduced from its architecture, dimensions, and separated location in the immediate vicinity of a large village. In our view, the enclosure represents communal infrastructure, the construction and use of which was probably collaborative. In this respect, it seems very plausible to us that the circular enclosure was used for integrative activities that were beneficial to the cohesion of the village community, whether they were of a ritual or a political nature.

Why was the rondel abandoned so early in the history of the large Borđoš settlement? A possible answer to this question may lie in the centripetal layout of both the tell and the flat settlement, which is discussed elsewhere more detailed (Hofmann *et al.* 2019). This settlement configuration, with a public square in the centre of the village, indicates a strong component of negotiation of communal concerns. What we cannot yet answer is whether the functions and institutions associated with the circular enclosure fell away or were transferred to other parts of the settlement.

Environmental reconstruction and subsistence

The remains of the Neolithic settlement of Borđoš lie on the Late Pleistocene Terrace close to the River Tisza alluvial plain. During the Neolithic occupation, the geomorphology was similar to what it is today, except that the River Tisza was located a bit to the east in comparison with its modern location. However, it was still a highly strategic position for a Neolithic settlement, surrounded by high environmental diversity associated with existing relief conditions. A pristine forest-steppe environment on the fertile loess terrace provided an opportunity for the development of settlement and agricultural activities. The several metres higher terrace protected the settlement from floods, and the alluvial plain of the River Tisza provides plenty of resources for Neolithic people.

From the analysis of the sediment cores from the north-eastern part of the ditch system at Borđoš, we can deduce that the early Holocene landscape of the site was probably forested. This is indicated by the presence of a (cambic) B-horizon and the old charcoal particles found at the base of the ditch backfill. The latter might

reflect the presence of a pristine woodland at Borđoš when the first Neolithic settlers appeared. Since this additional paleoenvironmental information would not be available without the radiocarbon ages of the charcoal from the ditch base, our study highlights the potential of dating wood charcoal, in addition to bones and seeds of more short-lived species.

Vegetation in the vicinity of a settlement is a natural bridge linking water availability to plants; soil; climate; and environmental factors, such as the cattle grazing/manuring effect and the rate of landscape and soil modification through human activities. Perhaps, the limited number of charcoal particles indicate that the prevailing vegetation on the loess terrace during the Late Neolithic was grassland with patches of xerothermic shrubs and small trees. The presence of the forest prior to the Neolithic settlement phase on the loess terrace is indicated by a buried, weakly developed cambic B-horizon at the site. The scenario of a land use – induced steppe formation (agricultural steppe) like that documented at Trypillian mega-sites in Ukraine (Kirleis and Dreibrodt 2016) can be neither excluded nor – due to the early presence of feather grass fragments – confirmed. Throughout evolution, humans seem to prefer „park-like" habitats, *e.g.* forest-grassland mosaics (Erdős *et al.* 2019). Oak and elm were common trees in the floodplain of the River Tisza. A similar taxonomic composition and a predominance of oak and elm in the charcoal assemblages have been documented for other Neolithic sites, from the area of Polgár, in the middle Tisza floodplain (Moskal-del Hoyo and Lityńska-Zając 2016). The combination of a dry, grassy plain suitable for plant cultivation and animal husbandry, on one hand, and a vast riverine forest full of game with permanent access to water supply from the nearby River Tisza, or its oxbow lake, on the other hand, offered excellent environments for different subsistence strategies.

The results of the Borđoš macro-botanical analysis indicate a type of plant economy that can be summarised as agro-gathering. At least two wheat species, einkorn and Zanduri wheat, as well as barley, were grown by the inhabitants of the Late Neolithic settlement. Additional foods, stone fruits (*Cornus mas*, *Prunus* sp.), wild strawberries (*Fragaria vesca*) and water caltrop (*Trapa natans*) were gathered in nearby forests or forest clearings and the stagnant waters of the river.

Based on the small sample size of the faunal bone remains, there is little potential to draw general conclusions for the animal portion of subsistence and diet of the Neolithic settlers at Borđoš. However, based on the sample analysed, we can state that the subsistence was likely based on domestic livestock herding complemented by the exploitation of wild resources.

Unio sp. are a genus of freshwater mussels, and representatives of this genus are abundant all across the tributary river system of the Danube. They were regularly exploited as a seasonal resource during the Neolithic (Clason 1979; Greenfield 1986). In case of *Helix* sp., there is no direct evidence of consumption, even though their shells are found in archaeological features of the area (Clason 1979; Greenfield 1986). However, it is possible these snails merely colonised places where subsistence remains were deposited.

Fishing and the consumption of freshwater resources was common all across the Tisza region and adjacent regions of the central Balkans during the Neolithic (Greenfield 1986; Bartosiewicz 2013). Wild resources, hunting, foraging and fishing played a crucial if regionally varying role during the Neolithic across Europe in complementing a subsistence mainly based on domestic livestock and cultivated plants (Orton 2009; 2012). In addition to catfish, pike and carp were likely a regular catch – and actually they still are today if you can believe the local hobby fishers.

We cannot determine based on the osteological remains whether European pond turtles (*i.e. Emys orbicularis*) are related to food consumption, because for reaching the flesh, the back armour segments can be broken and do not need to

be cut (see Degerböl and Krog 1951). European pond turtles are usually found in wetlands surrounded by wooded landscapes, but they are also found in the open steppe; because they are semi-aquatic, they can move away hundreds of metres away from water bodies (Ficetola and DeBernardi 2006; Marić 2013). The determining ecological factor for the distribution of European pond turtles is a summer temperature optimum of 22-24°C (Müller 1987).

Most of the bone fragments in the assemblage were identified as cattle. Domestic cattle (*Bos taurus*) were by far the most important herd animal in the livestock subsistence – based communities of the Late Neolithic in the central Balkans, where it was exploited for both meat and milk and kept as an investment for future exchanges (Greenfield 1986; Orton 2012). Finds of European hare (*Lepus europaeus*) at contemporary sites across the central Balkans have been described as the remains of ubiquitous small hunted game (comp. Greenfield 1986; Schwartz 1992; Russell 1993); however, we cannot make conclusions on its relevance to human subsistence based on a single fragment.

From the time of the abandonment of the Neolithic settlement until today, a chernozem-like soil of a thickness of ca. 40 cm has formed at the surface. This is similar to findings at other prehistoric sites in Europe (*e.g.* Fol *et al.* 1988; Kirleis and Dreibrodt 2016; Dreibrodt *et al.* 2022) and thus adds to indication for early anthropogenic influence on chernozem formation in Europe.

Conclusion

The interdisciplinary investigation of a circular enclosure at the Late Neolithic settlement of Borđoš, near Novi Bečej, in the Serbian province of Vojvodina, resulted in important new findings on both the history of this particular type of monument, the human subsistence strategies, and the environment in the lower reaches of the River Tisza during the Neolithic. Our dating has shown that Borđoš is probably one of the earliest (and largest) circular enclosures in Europe known thus far, dating back to the time before 5000 BCE. The appearance of these enclosures just in a contact zone between the 'Vinča world' of the Balkans and the Neolithic societies of the eastern Pannonian Plain, represented by the Tisza pottery tradition, again, raises the question of their origin, especially because new finds in other regions, such as the Banat and Slavonia, prove that our knowledge of this type of monument and its spatial distribution is still incomplete. At Borđoš, the fill of the ditch from the time after the use of the circular enclosure proved to be a valuable archive and reflects the deliberate selection of a settlement location with the greatest possible environmental diversity at the interface of the partly open forest-steppe landscape of the Borđoš loess terrace and the forested river landscape of the Tisza floodplain. The rich resources of this landscape were used by the inhabitants of the Borđoš settlement for a mixed subsistence based on the cultivation of cereals, keeping cattle, hunting small game, fishing and gathering wild plants.

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References

Adamiec, G. and Aitken, M., 1998. Dose-rate conversion factors: update. *Ancient TL*, 16 (2), 37-50.

AG Boden, 2005. *Bodenkundliche Kartieranleitung (KA5).* 5th edition. Hannover: AG Boden.

Aitken, M.J., 1985. *Thermoluminescence Dating*. London: Academic Press.

Archaeological Fish Resource. University of Nottingham. Available from: http://fishbone.nottingham.ac.uk/ [Accessed 24 March 2020]

Bánffy, E., Osztás, A., Oross, K., Zalai-Gaál, I., Marton, T., Nyerges, É.Á., 2013 (2016). The Alsónyék story: towards the history of a persistent place. *Bericht der Römisch-Germanischen Kommission*, 94 2013 (2016), 283-318.

Barker, G., 1975. Early Neolithic land use in Yugoslavia. *Proceedings of the Prehistoric Society*, 41, 85-104.

Bartosiewicz, L., 2013. Early Neolithic fishing in the Middle Tisza region, Hungary. *Archaeofauna*, 22, 133-144.

Behrensmeyer, A. K., 1978. Taphonomic and ecologic information from bone weathering. *Paleobiology*, 4 (2), 150-162.

Biagi, P., Shennan, S., Spataro, M., 2005. Rapid rivers and slow seas? New data for the radiocarbon chronology of the Balkan peninsula. *In:* L. Nikolova and J. Higgins, eds. *Prehistoric archaeology and anthropological theory and education*. Salt Lake City and Karlovo: International Institute of Anthropology, 43-51.

Bieniek A., Pokorný, P., 2005. A new find of macrofossils of feather grass (*Stipa*) in an Early Bronze Age storage pit at Vliněves, Czech Republic: local implications and possible interpretation in a central European context. *Vegetation History and Archaeobotany*, 14, 295-302. DOI:10.1007/s00334-005-0076-9

Biró T., K., 2005. Gyűjtemény és adatbázis: eszközök a pattintott kőeszköz nyersanyag azonosítás szolgálatában [Collection and database approach in the study of lithic raw material provenance]. *Archeometriai Műhely /Archaeometry Workshop*, 2 (4), 46-51.

Borić, D., 2015. The end of the Vinča world: modelling the Neolithic to Copper Age transition and the notion of archaeological culture. *In:* Hansen, S., Raczky, P., Anders, A., Reingruber, A., eds. *Neolithic and Copper Age between the Carpathians and the Aegean Sea: chronologies and technologies from the 6th to 4th millennia BCE*. Rahden: Verlag Marie Leidorf GmbH, 157-217.

Borić, D., Hanks, B., Šljivar, D., Kočić, M., Bulatović, J., Griffiths, S., Doonan, R., Jacanović, D., 2018. Enclosing the Neolithic world: a Vinča culture enclosed and fortified settlement in the Balkans. *Current Anthropology*, 59, 336-346.

Brennan, B.J., 2003. Beta doses to spherical grains. *Radiation Measurements*, 37, 299-303.

Brennan, B.J., Lyons, R.G., Phillips, S.W., 1991. Attenuation of alpha particle track dose for spherical grains. *International Journal of Radiation Applications and Instrumentation. Part D. Nuclear Tracks and Radiation Measurements*, 18, 249-253.

Breunig, P., 1987. *14C-Chronologie des vorderasiatischen, südost- und mitteleuropäischen Neolithikums*. Köln and Wien: Böhlau-Verlag.

Borojević, K., 2006. *Terra and Silva in the Pannonian Plain: Opovo agro-gathering in the Late Neolithic*. Oxford: British Archaeological Reports.

Bøtter-Jensen, L., Thomsen, K.J., Jain, M., 2010. Review of optically stimulated luminescence (OSL) instrumental developments for retrospective dosimetry. *Radiation Measurements*, 45, 253-257.

Bronk Ramsey, C., 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon*, 51, 337-360.

Cappers, R.T.J., Bekker, R.M., Jans, J.E.A., 2012. *Digitale zadenatlas van Nederland* [Digital seed atlas of the Netherlands], 2nd edition. Groningen Archaeological Studies 4. Groningen: Barkhuis and Groningen University Library.

Chapman, J., 2018. Climatic and human impact on the environment? A question of scale. *Quaternary International*, 496, 3-13.

Chapman, J., 2020. *Forging identities in the prehistory of old Europe: dividuals, individuals and communities 7000-3000 BC*. Leiden: Sidestone Press.

Clason, A. T., 1979. The farmers of Gomolava in the Vinča and La Tène period. *Rad Vojvođanskih Muzeja*, 25, 60-114.

Clark, A., 1996. *Seeing beneath the soil: prospecting methods in archaeology*. 2nd edition. London: B.T. Batsford.

Dammers, B., Franz, A., Sobott, R.G., Bente, K., 2014. Keramiktechnologie und kulturelle Identität am Beispiel von Uivar. *In:* Schier, W., Meyer, M., eds. *Vom Nil bis an die Elbe: Forschungen aus fünf Jahrzehnten am Institut für Prähistorische Archäologie der Freien Universität Berlin*. Rahden: Verlag Marie Leidorf GmbH, 25-46.

Dean, W. E., 1974. Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: comparison with other methods. *Journal of Sedimentary Petrology*, 44 (1), 242-248.

Dearing, J., 1999. *Environmental magnetic susceptibility: using the Bartington MS2 system*. 2nd edition. Kenilworth: Chi Publishing.

Degerböl, M.A. and Krog, H., 1951. *Den Europœiske Sumpskildpadde, Emys Orbicularis L., i Danmark: en Zoologisk og Geologisk Undersøgelse af Danske Postglaciale Fund og Deres Betydning for Bedømmelsen af Temperaturforholdene i Forhistorisk Tid*. Kobenhavn: C.A. Reitzels Forlag.

Dietze, M., Kreutzer, S., Burow, C., Fuchs, M. C., Fischer, M., Schmidt, C., 2016. The abanico plot: visualising chronometric data with individual standard errors. *Quaternary Geochronology*, 31, 12-18. DOI:10.1016/j.quageo.2015.09.003

Dreibrodt, S., Hofmann, R., Dal Corso, M., Bork, H.-R., Duttmann, R., Martini, S., Saggau, P., Schwark, L., Shatilo, L., Videiko, M., Nadeau, M.-J., Grootes, P. M., Kirleis, W., Müller, J., 2022. Earthworms, Darwin and prehistoric agriculture – chernozem genesis reconsidered. *Geoderma*, 409, 115607.

Duller, G.A.T., 2003. Distinguishing quartz and feldspar in single grain luminescence measurements. *Radiation Measurements*, 37 (2), 161-165.

Erdős, L., Ambarlı, D., Anenkhonov, O.A., Bátori, Z., Cserhalmi, D., Kiss, M., Kröel-Dulay, G., Liu, H., Magnes, M., Molnár, Z., Naqinezhad, A., Semenishchenkov, Y.A., Tölgyesi, Cs., Török, P., 2019. Where forests meet grasslands: forest-steppes in Eurasia. *Palaearctic Grasslands*, 40, 22-26.

Falkenstein, F., 1998. *Die Siedlungsgeschichte des Titeler Plateaus. Feudvar, Ausgrabungen und Forschungen in einer Mikroregion am Zusammenfluss von Donau und Theiß II*. Kiel: Oetker-Voges Verlag.

Ficetola, G.F. and De Bernardi, F., 2006. Is the European 'pond' turtle, Emys orbicularis strictly aquatic and carnivorous? *Amphibia-Reptilia* 27 (3), 445-447.

Fol, A., Katinĉarov, R., Lichardus, J., 1988. Die bulgarisch-deutschen Ausgrabungen in Drama. *In:* Fol, A. and Lichardus, J., eds. *Macht, Herrschaft, Gold. Das Gräber-*

feld von Varna (Bulgarien) und die Anfänge einer neuen europäischen Zivilisation. Saarbrücken: Verlag Moderne Galerie des Saarland-Museums, 151-180.

Grant, A., 1982. The use of tooth wear as a guide to the age of domestic animals. *In:* Wilson, B., Grigson, C., Payne, S., eds. *Ageing and sexing animal bones from archaeological sites*. Oxford: BAR Publishing, 91-108.

Greenfield, H., 1986. *The paleoeconomy of the central Balkans (Serbia): a zooarchaeological perspective on the Late Neolithic and Bronze Age (ca. 4500-1000 B.C.)*. BAR International Series S304. Oxford: BAR Publishing.

Grginčević M., Pujin V., Maletin S., Kostić, D., 1987. Prilog poznavanju rasporeda i broja radijalnih kanalića na krljuštima nekih šaranskih riba. *Biosistematika*, 13, 151-158.

Hammer, Ø., Harper, D.A.T., Ryan, P.D., 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica*, 4 (1), 9-18.

Heuzé V., Thiollet, H., Tran, G., Lebas, F., 2017. Cockspur grass (*Echinochloa crus-galli*) forage. *In: Feedipedia*. Available from: https://feedipedia.org/node/451 [Accessed 24 Oct 2019]

Hofmann, R., 2013. *Okolište 2 – Spätneolithische Keramik und Siedlungsentwicklung in Zentralbosnien*. Universitätsforschungen zur prähistorischen Archäologie 243. Bonn: Dr. Rudolf Habelt GmbH.

Hofmann, R., Medović, A., Furholt, M., Medović, I., Stanković Pešterac, T., Dreibrodt, S., Martini, S., Hofmann, A., 2019. Late Neolithic multicomponent sites of the Tisza region and the emergence of centripetal settlement layouts. *Prähistorische Zeitschrift*, 94, 1-28.

Ivanova, M., De Cupere, B., Ethier, J., Marinova, E., 2018. Pioneer farming in southeast Europe during the early sixth millennium BC: climate-related adaptations in the exploitation of plants and animals. *PLoS One*, 13 (5), e0197225. DOI:10.1371/journal.pone.0197225

Kalafatić, H., Šiljeg, B., 2018. Krugovi Parnjaci: novi uvidi u neolitičke obrasce naseljavanja [Twin circles: new insights in the Neolithic settlement pattern]. *Prilozi Instituta za Arheologiju u Zagrebu*, 35, 71-109.

Kenéz, Á., Pető, Á., Gyulai, F., 2014. Evidence of 'new glume wheat' from the Late Neolithic (Copper Age) of south-eastern Hungary (4th millennium cal. b.c.). *Vegetation History and Archaeobotany*, 23, 551-566. DOI:10.1007/s00334-013-0405-3

Kirleis, W. and Dreibrodt, S., 2016. The natural steppe background: forest, forest steppe, or steppe environment. *In:* Müller, J., Rasmmann, K., Videiko, M., eds. *Trypillia mega-sites and European prehistory: 4100-3400 BCE*. London and New York: Routledge Taylor and Francis, 171-180.

Kohler-Schneider, M., 2003. Contents of a storage pit from Late Bronze Age Stillfried, Austria: another record of the 'new' glume wheat. *Vegetation History and Archaeobotany*, 12, 105-111. DOI:10.1007/s00334-003-0010-y

Kostić, D. and Maletin, S., 1988. Faktor krljušti I broji raspored radijalnih kanalića na krljuštima srebrnog karaša (Carassius auratus gibelio, Bloch) ikaraša (Carassius carassius L.) iz Palića I Obedske bare. *In: Zbornik referata Naučnog skupa Minerali, stijene, izumrli i* živi *svijet Bosne i Hercegovine, Sarajevo, 7-8 oktobar 1988. godine*. Sarajevo: Zemaljski muzej Bosne i Hercegovine, 541-546.

Kreutzer, S., Schmidt, C., Fuchs, M.C., Dietze, M., Fischer, M., Fuchs, M., 2012. Introducing an R package for luminescence dating analysis. *Ancient TL*, 30 (1), 1-8.

Kroll, H., 2013. Bericht über die Pflanzenfunde aus Okolište Haus 38. *In:* Müller, J., Rassmann, K., Hofmann, R., eds. *Okolište 1 – Untersuchungen einer spätneolitischen Siedlungskammer in Zentralbosnien*. Bonn: Dr. Rudolf Habelt GmbH, 113-122.

Lazarovici, G., 1979. *Neoliticul Banatului: Muzeulde Istorie al Transilvaniei*. Cluj-Napoca: Muzeul de Istorie al Transilvaniei.

Lazarovici, G., 2013. Despre sistemele de fortificatii neolitice din Transilvania si Banat (Partea I-A Fortificatiile neolitice). *In: Peregrinari arheologice* între *estul* şi *vestul Europei. Studii* în *onoarea lui Tiberius Bader la aniversarea de 75 de ani/Archäol-*

ogische Wanderungen zwischen Ost- und Westeuropa. Studien für Tiberius Bader zum 75. Geburtstag / Régészeti barangolások kelet és nyugat Európa között. Tanulmányok a 75 éves Tiberius Bader tiszteletére. Satu Mare: Editura Muzeului Satmarean Satu Mare, 55-110.

Legge, A.J., 1992. *Excavations at Grimes Graves, Norfolk, 1972-1976: animals, environment and the Bronze Age economy*. London: British Museum Press.

Limburský, P., Řídký, J., Šumberová, R., Končelová, M., 2019. Radiocarbon dating in action. *In:* Řídký, J., Květina, P., Limburský, P., Končelová, M., Burgert, P., Šumberová, R., eds. *Big men or chiefs? Rondel builders of Neolithic Europe*. Oxford and Philadelphia: Oxford University Press, 103-134.

Link, T., 2006. *Das Ende der neolithischen Tellsiedlungen: ein kulturgeschichtliches Phänomen des 5. Jahrtausends v. Chr. im Karpatenbecken*. Universitätsforschungen zur prähistorischen Archäologie 134. Bonn: Dr. Rudolf Habelt GmbH.

Literski, N. and Nebelsick, L.D., 2012. Katalog der Kreisgrabenanlagen und verwandten Tells der ersten Hälfte des 5. Jt. v. Chr. in Mittel- und Südosteuropa. *In:* F. Bertemes and H. Meller, eds. *Neolithische Kreisgrabenanlagen in Europa. Neolithic circular enclosures in Europe. Internationale Arbeitstagung 7.-9. Mai 2004 in Goseck (Sachsen-Anhalt). International workshop 7th-9th May in Goseck (Saxony-Anhalt, Germany)*. Halle: Landesmuseum für Denkmalpflege und Archäologie Sachsen-Anhalt and Landesmuseum für Vorgeschichte, 433-507.

Lüning, J., 1988. Zur Verbreitung und Datierung bandkeramischer Erdwerke. *Archäologisches Korrespondenzblatt*, 18, 155-168.

Marić, M., 2013. The Vinča culture: climate and environment in the Danube region in the 6th and 5th millenium BC. *In:* Popović, L.Č., Vidaković, M., Kostić, D.S., eds. *Resources of Danubian region: the possibility of cooperation and utilization*. Belgrade: Humboldt-Club Serbien, 204-232.

Mauz, B., Bode, T., Mainz, E., Blanchard, H., Hilger, W., Diekau, R., Zöller, L., 2002. The luminescence dating laboratory at the University of Bonn: equipment and procedures. *Ancient TL*, 20 (2), 53-61.

Mauz, B., Packman, S., Lang, A., 2006. The alpha effectiveness in silt-sized quartz: new data obtained by single and multiple aliquot protocols. *Ancient TL*, 24 (2), 47-52.

Meadows, J., 2019. Radioacarbon dating and Bayesian chronological modelling, *In:* Spataro, M. ed. *Starčevo ceramic technology: the first potters of the Middle Danube Basin*. Universitätsforschungen zur prähistorischen Archäologie 341. Bonn: Dr. Rudolf Habelt GmbH, 34-43.

Medović, A., 2019. Feathergrass in the vase and Sanduri wheat in the field – Environment and land use in the Bordos microregion after the botanical record. *In:* Kirleis, W., Müller, J., Weinelt, M. eds. *International open workshop socio-environmental dynamics over the last 15,000 years: the creation of landscapes VI. Kiel University, March 11-16, 2019. Programme & Abstracts. Kiel: Graduate School 'Human Development in Landscapes' and ROOTS – Social, Environmental, and Cultural Connectivity in Past Societies, CRC 1266, Scales of Transformation*, 99.

Medović, A. and Horváth, F., 2012. Content of a storage jar from the Late Neolithic site of Hódmezővásárhely-Gorzsa, south Hungary: a thousand carbonized seeds of Abutilon theophrasti Medic. *Vegetation History and Archaeobotany*, 21, 215-220. DOI: 10.1007/s00334-011-0319-x

Medović, A., Hofmann, R., Stanković Pešterac, T., Dreibrodt, S., Medović, I., Pešterac, R., 2014. *The Late Neolithic settlement mound Borđoš near Novi Bečej, Serbian Banat, in a multiregional context – preliminary results of geophysical, geoarchaeological and archaeological research*. Rad Muzeja Vojvodina, 56, 53-77.

Meyer, M. and Raetzel-Fabian, D., 2006. Neolithische Grabenwerke in Mitteleuropa. Ein Überblick. *Journal of Neolithic Archaeology*, 8. DOI: 10.12766/jna.2006.20

Moskal-del Hoyo, M., Lityńska-Zając, M., 2016. Plant remains from the Late Neolithic settlement of Polgár-Bosnyákdomb. *Folia Quaternaria*, 84, 85-98.

Müller, G., 1987. *Schildkröten. Land-, Sumpf- und Wasserschildkröten im Terrarium*. Stuttgart: Ulmer Verlag.

Müller, J., 2006. Demographische Variablen des Bosnischen Spätneolithikums – zur Frage der Bevölkerungsrekonstruktion im südosteuropäischen Neolithikum. *In:* N. Tasić and C. Grazdanov, eds., *Homage to Milutin Garašanin*. Belgrade: Serbian Academy of Sciences and Arts, 367-378.

Müller, J., Rassmann, K., Kujundžić-Vejzagić, Z., 2013. Okolište – Rekonstruktion spätneolithischer und frühchalkolithischer Siedlungsprozesse des zentralbosnischen Visokobeckens: Fragestellungen, Forschungsstrategien, Ergebnisse. *In:* Müller, J., Rassmann, K., Hofmann, R., eds. *Okolište 1 – Untersuchungen einer spätneolithischen Siedlungskammer in Zentralbosnien*. Universitätsforschungen zur prähistorischen Archäologie 228. Bonn: Dr. Rudolf Habelt GmbH, 11-68.

Murray, A.S., Wintle, A.G., 2000. Luminescence dating of quartz using and improved single-aliquot regenerative protocol. *Radiation Measurements*, 32, 571-577.

Murray, A.S., Wintle, A.G., 2003. The single aliquot regenerative dose protocol: potential for improvements in reliability. *Radiation Measurements*, 37 (4-5), 377-381.

Nádor, A., Lantos, M., Tóth-Makk, Á., Thamó-Bozsó, E., 2003. Milankovitch-scale multi-proxy records from fluvial sediments of the last 2.6 Ma, Pannonian Basin, Hungary. *Quaternary Science Reviews*, 22, 2157-2175.

Orton, D.C., 2009. False dichotomies? Balkan Neolithic hunting in archaeological context. *In:* Mulville, J. and Powel, A., eds. *A walk on the wild side: hunting in farming societies*. Oxford: Oxbow Books, 148-154.

Orton, D.C., 2012. Herding, settlement, and chronology in the Balkan Neolithic. *European Journal of Archaeology*, 15 (1), 5-40.

Outram, A. K., 2001. A new approach to identifying bone marrow and grease exploitation: why the 'indeterminate' fragments should not be ignored. *Journal of Archaeological Science*, 28 (4), 401-410.

Parkinson, W.A., Gyucha, A., 2012. Long term social dynamics and the emergence of hereditary inequality: a prehistoric example from the Carpathian Basin. *In:* T.L. Kienlin and A. Zimmermann, eds. B*eyond elites: alternatives to hierarchical systems in modelling social formations. International conference at the Ruhr-Universität Bochum, Germany, October* 22-24, 2009. Bonn: Dr. Rudolf Habelt GmbH, 243-249.

Petrasch, J., 1990. Mittelneolithische Kreisgrabenanlagen in Mitteleuropa. *Bericht der Römisch-Germanischen Kommission*, 71 1990, 409-564.

Pickartz, N., Rabbel., W., Rassmann, K., Müller-Scheeßel, N., Furholt, M., Müller, J., Cheben, I., Wilken, D., Wunderlich, T., Dreibrot, S., 2020. What over 100 drillings tell us: a new method for determining the Koenigsberger ratio of soils from magnetic mapping and susceptibility logging. *Archaeological Prospection*, 27 (4), 393-414.

Plath, T., 2012. *Nutzungsinterpretationen mittelneolithischer Kreisgrabenanlagen. Vom archäologischen Befund zur glaubhaften Deutung*. Saarbrücken: Südwestdeutscher Verlag für Hochschulschriften.

Porčić, M., 2011. An exercise in archaeological demography: estimating the population size of Late Neolithic settlements in the central Balkans. *Documenta Praehistorica*, 38, 323-332.

Porčić, M., Blagojević, T., Pendić, J., Stefanović, S., 2020. The Neolithic demographic transition in the central Balkans: population dynamics reconstruction based on new radiocarbon evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 376 (1816), 1-8.

Prescott, J.R. and Hutton, J.T., 1994. Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long-term time variations. *Radiation Measurements*, 23 (2-3), 497-500.

Rabenhorst, M.C., Schmehling, A., Thompson, J.A., Hirmas, D. R., Graham, R.C., Rossi, A.M., 2014. Reliability of soil color standards. *Soil Science Society of America Journal*, 79, 193-99.

Raczky, P. and Anders, A., 2012. Neolithic enclosures in eastern Hungary and their survival into the Copper Age. *In:* F. Bertemes and H. Meller, eds., *Neolithische Kreisgrabenanlagen in Europa. Neolithic circular enclosures in Europe. Internationale Arbeitstagung 7.-9. Mai 2004 in Goseck (Sachsen-Anhalt). International workshop 7th-9th May 2004 in Goseck (Saxony-Anhalt, Germany)*. Halle: Landesamt für Denkmalpflege und Archäologie Sachsen und Landesmuseum für Vorgeschichte, 271-309.

Raczky, P. and Sebők, K., 2014. The outset of Polgár-Csőszhalom tell and the archaeological context of a special central building. *In:* S. Forţiu and A. Cîntar, eds. *ArheoVest II1: In Honorem Gheorghe Lazarovici, Interdisciplinaritate* în *Arheologie*. Szeged: JATE Press Kiadó, 51-100.

Raczky, P., Fodor, I., Mester, Zs., 2010. Régészeti Kutatások Hajdúböszörmény – Pródi-Halmon [Archaeological research at Hajdúböszörmény – Pródi-Halom, Hungary]. *Archaeologiai* Értesítő, 135, 161-182.

Raczky, P., Anders, A., Bartosiewicz, L., 2011. The enclosure system of Polgár Csőszhalom and its interpretation. *In:* S. Hansen and J. Müller, eds. *Sozialarchäologische Perspektiven. Gesellschaftlicher Wandel 5000-1500 v. Chr. zwischen Atlantik und Kaukasus. Internationale Tagung 15.-18. Oktober 2007 in Kiel*. Darmstadt: Phillip von Zabern, 57-80.

Raczky, P., Anders, A., Sebők, K., Csippán, P., Tóth, Zs., 2015. The times of Polgár-Csőszhalom: chronologies of human activities in a Late Neolithic settlement in north-eastern Hungary. *In:* Hansen, S., Raczky, P., Anders, A., Reingruber, A., eds. *Neolithic and Copper Age between the Carpathians and the Aegean Sea: chronologies and technologies from the 6th to the 4th millennium BCE. International workshop Budapest 2012*. Bonn: Dr. Rudolf Habelt GmbH, 21-48.

Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hajdas, I., Heaton, T., Hogg, A., Hughen, K., Kromer, B., Manning, S., Muscheler, R., Palmer, J., Pearson, C., van der Plicht, J., Reimer, R., Richards, D., Scott, E., Southon, J., Turney, C., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., Talamo, S., 2020. The IntCal20 northern hemisphere radiocarbon age calibration curve (0-55 cal kBP). *Radiocarbon*, 62 (4), 725-757.

Řídký, J., 2019. Rondels – structural elements, original appearance and construction. *In:* Řídký, J., Květina, P., Limburský, P., Končelová, M., Burgert, P., Šumberová, R., eds. Big men or chiefs? Rondel builders of Neolithic Europe. Oxford and Philadelphia: Oxbow Books, 66-101.

Řídký, J., Květina, P., Limburský, P., Končelová, M., Burgert, P., Šumberová, R., eds., 2019. *Big men or chiefs? Rondel builders of Neolithic Europe*. Oxford and Philadelphia: Oxbow Books.

Rühl, L., Herbig, C., Stobbe, A., 2015. Archaeobotanical analysis of plant use at Kamennyi Ambar, a Bronze Age fortified settlement of the Sintashta culture in the southern Trans-Urals steppe, Russia. *Vegetation History and Archaeobotany*, 24, 413-426. DOI: 10.1007/s00334-014-0506-7

Russell, N., 1993. *Hunting, herding and feasting: human use of animals in Neolithic southeast Europe*. Unpublished PhD dissertation, University of California, Berkeley.

Sanmartín, P., Chorro, E., Vázquez-Nion, D., Martínez-Verdú, F. M., Prieto, B., 2014. Conversion of a digital camera into a non-contact colorimeter for use in stone cultural heritage: the application case to Spanish granites. *Measurement*, 56, 194-202.

Schier, W. and Draşovean, F., 2004. Vorbericht über die rumänisch-deutschen Prospektionen und Ausgrabungen in der befestigten Teilsiedlung von Uivar, jud. Timiş, Rumänien (1998-2002). *Prähistorische Zeitschrift*, 79, 145-230.

Schoch, W., Heller, I., Schweingruber, F., Kienast, F., 2004. *Wood anatomy of central European Species*. Available from: www.woodanatomy.ch [Accessed 12 Jul 2020]

Schwartz, C.A., 1992. Zarkovo-Ledine: the vertebrate and molluscan remains 1948 season. *Zbornik Narodnog Muzeja*, 14, 123-133.

Slavnić, Ž., 1952. NizinskešumeVojvodine / Die Niederungswälder der Vojvodina. *Zbornik Matice srpske za prirodne nauke*, 2, 17-38.

Sheppard, R., 1823. XI. Descriptions of seven new British land and fresh-water shells, with observations upon many other species, including a list of such as have been found in the County of Suffolk. *Transactions of the Linnean Society of London*, 14 (1), 148-170.

Sommer, U., 1991. *Studien zur Siedlungsarchäologie I – Zur Entstehung archäologischer Fundvergesellschaftungen: Versuch einer archäologischen Taphonomie*. Universitätsforschungen zur prähistorischen Archäologie 6. Bonn: Dr. Rudolf Habelt GmbH, 51-193.

Tasić, N., Marić, M., Filipović, D., Penezić, K., Dunbar, E., Reimer, P., Barclay, A., Bayliss, A., Gaydarska, B., Whittle, A.W.R., 2016. Interwoven strands for refining the chronology of the Neolithic tell of Vinča-Belo Brdo, Serbia. *Radiocarbon*, 58, 1-37.

Tringham, R. and Krstić, D., eds., 1990. *Selavac: a Neolithic village in Yugoslavia*. Monumenta Archaeologica 15. Los Angeles: Institute of Archaeology, University of California.

Tringham, R. and Krstić, D., 1990. Conclusion: Selevac in the Wider Context of European Prehistory. *In:* R. Tringham and D. Krstić, eds. *Selevac: a Neolithic village in Yugoslavia*. Monumenta Archaeologica 15. Los Angeles: Institute of Archaeology, University of California, 567-616.

Vandenberghe, J., Kasse, C. K., Popov, D., Marković, S. B., Vandenberghe, D., Bohncke, S. and Gábris, G., 2018. Specifying the external impact on fluvial lowland evolution: the Last Glacial Tisza (Tisa) catchment in Hungary and Serbia. *Quaternary*, 1 (2), 14.

Viscarra Rossel, R.A., Minasny, B., Roudier, P., McBratney, A.B., 2006. Colour space models for soil science. *Geoderma*, 133, 320-337.

Vondrovský, V., Kovačiková, L., Smejtek, L., 2022. Neolithic rondels in central Europe and their builders: an analysis of multi-rondel sites. *Antiquity*, 96 (389), 1105-1123.

Whittle, A.W.R., ed., 2007. *The Early Neolithic on the Great Hungarian Plain: investigations of the Körös culture site of Ecsegfalva 23, County Békés*. Budapest: Archaeological Institute of the Hungarian Academy of Sciences.

Whittle, A.W.R., Bayliss, A., Barclay, A., Gaydarska, B., Bánffy, E., Borić, D., Draşovean, F., Jakucs, J., Marić, M., Orton, D., Pantović, I., Schier, W., Tasić, N., Linden, M.V., 2016. A Vinča potscape: formal chronological models for the use and development of Vinča ceramics in south-east Europe. *Documenta Praehistorica*, 43, 1-60.

Wilkes, F., 2019. *Settlement and landscape development of the Borđoš plateau, Serbia*. Unpublished master's thesis. Institute for Pre- and Protohistoric Archaeology, Kiel.

PART 4. ECONOMY AND SUBSISTENCE STRATEGIES

The animal economy of the Lengyel culture population in Slovakia and the case study of Kiarov (central Slovakia)

Noémi Beljak Pažinová, Katarína Šimunková, Alena Bistáková

Abstract

The study reflects the current state of knowledge about the animal economy of the Lengyel culture in what is today Slovakia, based on archaeozoological data. We present the results of an analysis of animal remains from settlement features at three sites of the Lengyel and Epi-Lengyel cultures discovered in the cadastre of Kiarov, in central Slovakia, including the spectrum of domesticated and hunted animals, the anatomical distribution of individual taxa, and any intentional modification of the bones. The results indicate a focus on domesticated livestock, with only occasional hunting of wild ungulates. We address the lack of preserved sources and their importance, as well as the inter-site variation in the frequency of cattle, ovicaprids, and pigs and suggest it may imply variation in subsistence tactics. However, larger sample numbers are required to verify these patterns.

Keywords: *Lengyel culture, Slovakia, archaeozoology, animal economy, subsistence practices*

Introduction

The spread of plant agriculture and animal husbandry into central Europe during the 6th millennium BCE initiated various transformations in local subsistence strategies and landscape use. Ongoing research is providing new insights into regional variation in subsistence practices of the first farming communities (Linear Pottery culture) (*e.g.* Bartosiewicz 2005; Oross and Bánffy 2009; Schmitzberger 2009; Tóth *et al.* 2011; Furholt *et al.* 2014, 2020). The primary territory of the subsequent Lengyel culture, whose settlement and subsistence in central eastern Europe develop around 4900/4800 BCE, in the Late Neolithic (Manning *et al.* 2014, 1077; Regenye *et al.* 2020, 49, 54), was located in Transdanubia and

south-western Slovakia (Pavúk 2007; Barna 2011, 2017). The Classic Lengyel culture phase is characterised by a typical material expression and maximum territorial expansion (secondary settlement territory) extending to Austria (Moravian – eastern-Austrian group) and Moravia (Moravian Painted Pottery culture) in the west and to the periphery of eastern Slovakia in the east (*e.g.* Pavúk 1981, 257-259; Ruttkay 1995; Čižmář *et al.* 2004, 209; Stadler *et al.* 2006; Stadler and Ruttkay 2007). The end of the Classic Lengyel culture, which does not include Epi-Lengyel, falls in the interval 4450-4300 BCE (Diaconescu 2014, 30, 39, Fig. 26, Table 1). Based on radiocarbon dates, Eva Lenneis (2017, 397) puts the end of the Lengyel culture at 4115 BCE, which is similar to Manning *et al.* (2014, 1077), whose modelling dates the end to 4137 BCE.

The subsequent Epi-Lengyel culture, with the first signs of the use of copper, marking the dawn of the Early Copper Age in central Europe, is a rather heterogeneous culture complex, with various duration lengths in different regions. The period is characterised in south-western Slovakia by the presence of the Ludanice culture group (Pavúk 2000, 2010; Čižmář *et al.* 2004; Gabulová *et al.* 2022, 149-161). In central Slovakia, little is known about the end of the Epi-Lengyel, other than that the region proceeds into a considerable time dispersion approximately 4000-3600 BCE, followed by the beginning of the Baden culture (Proto-Boleráz phase; Stadler *et al.* 2001, Table 8; Horváth *et al.* 2008, 452, 453, Table 2).

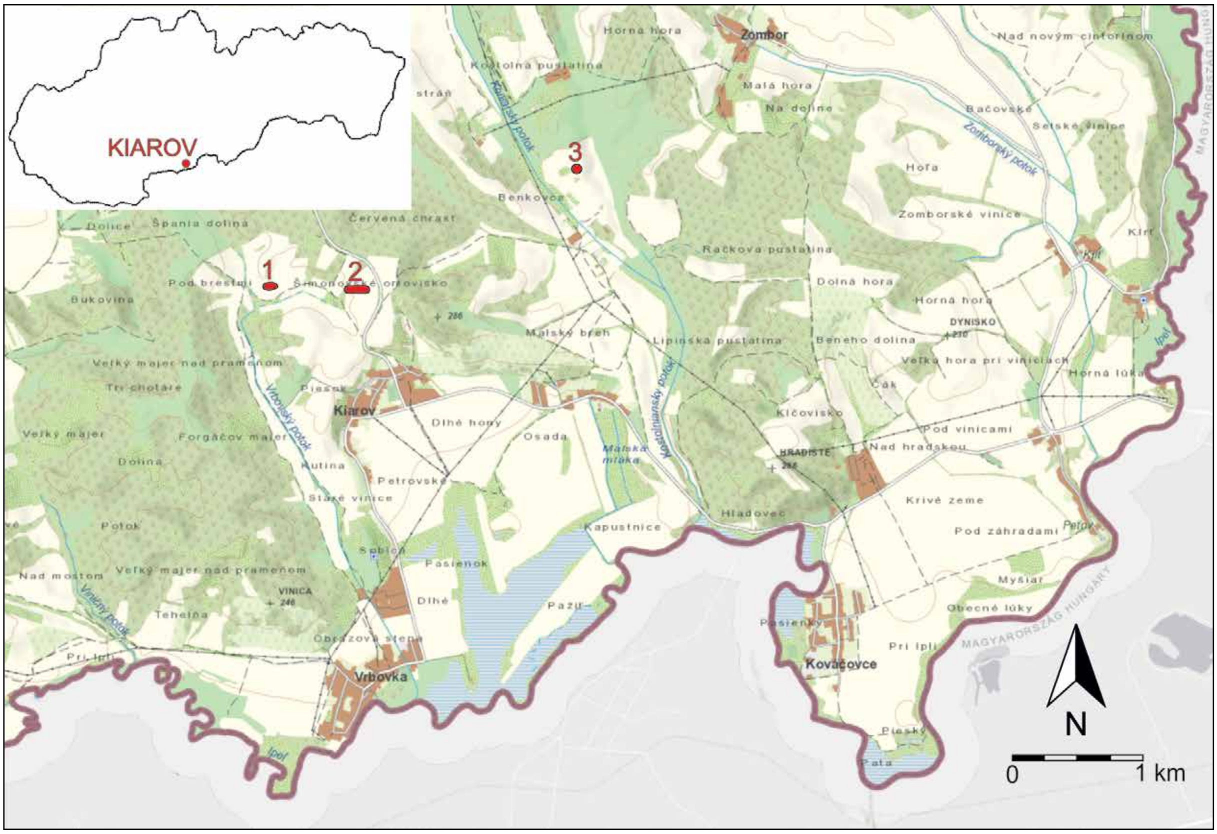
Generally, not much is known about Lengyel culture subsistence practices (including farming) in Slovakia, since data are available from only a few sites across the region. Of the sites that have relevant bioarchaeological remains, only a few have had comprehensive zooarchaeological analyses, mostly in the distant past (*e.g.* Ambros 1961, 1986; Fabiš 1994, 1995, 1997; Cheben *et al.* 2001; Moser 2011; Holub 2022, 175-178), and the quality of the bioarchaeological evidence is variable. More recently, research in Slovakia is gradually providing new insights into regional variation in subsistence practices and production strategies.

In the present study we look at the animal economy in the Lengyel culture and Epi-Lengyel period in Slovakia through the available archaeozoological remains and express our views on some of the key issues we face regarding its value and coverage. As a case study, we present the Lengyel culture and Epi-Lengyel sites of Kiarov, Veľký Krtíš district, Slovakia, which offer the possibility to study faunal assemblages from different Lengyel culture settlements located in the same region in central Slovakia and to explore variation in animal exploitation practices. In the following discussion, point out geographic differences in the frequency of domesticated and hunted animals among the different Lengyel culture sites.

Case study: faunal assemblage from the Lengyel culture and Epi-Lengyel sites of Kiarov (central Slovakia)

Material and methods

The analysed faunal remains were found during rescue excavations in advance of construction of the DN 800 Slovakia-Hungary gas pipeline, under the auspices of the Institute of Archaeology SAS in Nitra, Slovakia, in 2013 (Beljak Pažinová and Beljak 2014). Three sites yielded animal bones (Fig. 1): Veľké ortovisko (6 features, B4, B5, B7, B10, B11, B15, out of 15), Šimonovské ortovisko (16 features, C1, C2, C4, C5, C6, C7, C8, C9, C10, C13, C14, C15, C16, C17, C18, C19, out of 19), and Nad Kiarovskou pustatinou (1 feature, D2, out of 2). Veľké ortovisko and Šimonovské



ortovisko are at a distance of up to 0.7 km from each other in the northern part of the cadastre. Nad Kiarovskou pustatinou is located on the north-eastern edge of the cadastre municipality, at least 2 km from the other two sites, on top of a lower hill.

Figure 1. Map of central Slovakia showing the location of Kiarov (inset) and the Lengyel and Epi-Lengyel culture sites with zooarchaeological material mentioned in the text. 1 Veľké ortovisko; 2 Šimonovské ortovisko; 3 Nad Kiarovskou pustatinou.

The faunal osteological material comes exclusively from settlement features, and its date was determined based either on other archaeological artefacts found within the feature or on AMS radiocarbon dating of selected bone fragments (Table 1). In total, 1122 bone fragments were analysed, totalling ca. 4.7 kg in weight. Out of that number, 610 bone fragments, totalling 716.26 g, remain unidentified, that is, they were categorised either as indeterminate or as belonging to one of the auxiliary categories, of small, medium or large mammal. The average fragment weights are as follows: small mammal 0.6 g, medium mammal 1.16 g, large mammal 3.72 g, indeterminate 0.73 g.

Identification of anatomical part and taxonomic identity was carried out by direct comparison with the researchers' modern comparative collection and by consulting available publications in veterinary science, anatomy and zooarchaeology (Kolda 1951; Schmid 1972; Popesko 2007; Adams and Crabtree 2008; Bocheński and Tomek 2009a, 2009b; France 2009). Fragments that could not be identified to species or other analytically useful taxonomic category were assigned to auxiliary categories commonly used in archaeozoological publications, based on their size, weight, and structure: large mammal (the size of a horse, domestic cattle or red deer), medium mammal (the size of a caprine, pig, roe deer or large dog), and small mammal (the size of a rodent). The subfamily Caprinae in this case refers to domestic sheep and domestic goat. Whenever the determination marks used in the respective sources were present, these osteologically similar species were differentiated, using publications by Joachim Boessneck (1969), Sebastian Payne (1973); Paul Halstead, Patricia Collins, and Valasia Isaakidou (1995; Halstead

Laboratory code	Context	Site	Species (anatomical element)	Age BP	Age calBC (2σ)	Period
DebA [8-10]	CB44A, Feature 19	Kiarov – Šimonovské ortovisko	*Ovis capra* (phalanx 2)	5712 ± 32	4673-4456 BC	Lengyel I
DebA [8-10]	CB44B, Feature 19	Kiarov – Šimonovské ortovisko	*Ovis capra* (calcaneus)	5734 ± 32	4684-4493 BC	Lengyel I
DebA [8-10]	BB13, Feature 11	Kiarov – Veľké ortovisko	*Bos taurus* (phalanx 1)	5166 ± 48	4161-3801 BC	Lengyel
DebA [8-10]	CB14B, Feature 6	Kiarov – Šimonovské ortovisko	*Ovis capra* (astragalus)	4893 ± 28	3713-3634 BC	Epi-Lengyel
DebA [8-10]	CB14A, Feature 6	Kiarov – Šimonovské ortovisko	*Bos taurus* (phalanx 2)	4785 ± 31	3640-3521 BC	Epi-Lengyel
DebA [8-10]	CB02, Feature 6	Kiarov – Šimonovské ortovisko	*Sus domesticus* (scapula)	4847 ± 26	3696-3536 BC	Epi-Lengyel
DebA [8-10]	DB01, Feature 2	Kiarov – Nad Kiarovskou pustatinou	*Ovis capra* (humerus)	5035 ± 26	3949-3764 BC	Epi-Lengyel
DebA [8-10]	DB03, Feature 2	Kiarov – Nad Kiarovskou pustatinou	*Ovis capra* (femur)	4952 ± 26	3781-3660 BC	Epi-Lengyel

Table 1. List of mammal bone samples from the Lengyel sites in the municipality of Kiarov (Slovakia) subjected to AMS dating. Dates are calibrated using OxCal v. 4.4.1 (Reimer et al. 2020).

et al. 2002); and Bradley Adams and Pamela Crabtree (2008). Differentiation between the aurochs (*Bos primigenius*) and domestic cattle (*Bos taurus*) was based on osteometric data if the state of the bone material allowed it, using publications by Henryk Kobryń and Alicja Lasota-Moskalewska (1989) and Erich Pucher (2020).

Items that were sufficiently complete were measured according to Angela von den Driesch (1976). The withers height was then determined based on the osteometric data (*e.g.* Vitt 1952; Fock 1966, cited by von den Driesch and Boessneck 1974; Teichert 1969; Harcourt 1974). The approximate age of each animal was determined using both epiphyseal fusion (Zoetis *et al.* 2003; Reitz and Wing 2008) and tooth eruption and wear (Payne 1973, 1987; Grant 1982; Hillson 2005). We also noted cultural taphonomic and pathological bone lesions (*e.g.* sawing, chopping, bone deformation), bone tissue preservation (Behrensmeyer 1978), and signs of heat alteration (Shipman *et al.* 1984; Thurzo and Beňuš 2005).

Quantification – in the form of number of identified specimens (NISP), minimum number of individuals (MNI), and bone weight – was based on standard methods (Klein and Cruz-Uribe 1984; Kyselý 2004; Reitz and Wing 2008). In the case of NISP, each bone or bone fragment was considered a single specimen (n=1), despite some fragments likely forming a single bone (*i.e.* an unfused epiphysis with certainty belonging to a specific diaphysis). An upper or a lower jawbone was considered a single unit, together with its teeth. MNI values were based on the total number of a single anatomical element, taking into consideration size, fragmentation, and biological age. Fragments that evidently belong together were considered a single hypothetical individual.

Results

Lengyel culture settlement (Lengyel I)

Kiarov, Veľké ortovisko

A total of 40 bone fragments, weighing 97.05 g in all, were recovered from Veľké ortovisko. Of these, 27 fragments were unidentified (Table 2). The identified species are domestic pig (*Sus domesticus*), red deer (*Cervus elaphus*), and caprine (*Ovis/Capra*). A single phalanx (phalanx 1) could not be assigned with certainty to either domestic cattle or aurochs. Hence it was designed as domestic cattle or aurochs (*Bos taurus/primigenius*). The assemblage includes only five fragments of domestic pig (teeth) and only one of red deer (an antler fragment) (Table 3).

		Lengyel I						Epi-Lengyel					
		Veľké ortovisko			Šimonovské ortovisko (Features C18, C19)			Šimonovské ortovisko			Nad Kiarovskou pustatinou		
Taxon	**Scientific name**	**NISP**	**MNI**	**weight (g)**	**NISP**	**MNI**	**weight (g)**	**NISP**	**MNI**	**weight (g)**	**NISP**	**MNI**	**weight (g)**
Sheep/goat	*Ovis/Capra*	6	1	6,34	24	2	108,18	179	4	529,79	5	1	7,85
Swine	*Sus domesticus*	5	1	2,98	7	1	95,8	58	2	325,78	2	2	3,41
Cattle	*Bos taurus*	-	-	-	49	2	884,17	16	1	302,78	-	-	-
Cattle/aurochs	*Bos taurus/primigenius*	1	1	67,13	-	-	-	65	1	731,63	2	1	6,01
Aurochs	*Bos primigenius*	-	-	-	-	-	-	2	1	370,62	-	-	-
Red deer	*Cervus elaphus*	1	1	1,14	8	1	127,88	2	-	74,15	-	-	-
Roe deer	*Capreolus capreolus*	-	-	-	6	1	30,62	30	2	260,14	2	1	54,11
Red fox	*Vulpes vulpes*	-	-	-	-	-	-	23	2	12,95	-	-	-
Birds	Aves sp.	-	-	-	-	-	-	1	1	0,72	-	-	-
Unionidae	Bivalvia, Unionidae sp.	-	-	-	5	1	2,11	-	-	-	-	-	-
Helicidae	Gastropoda, Helicidae sp.	-	-	-	-	-	-	6	1	0,17	-	-	-
White-lipped snail	*Cepaea hortensis*	-	-	-	-	-	-	1	1	1,74	-	-	-
Escargot	*Helix pomatia*	-	-	-	-	-	-	5	1	2,81	-	-	-
Indet.		1	-	0,64	84	-	99,99	248		141,71	-	-	-
Small mammal		-	-	-	-	-	-	15		8,24	-	-	-
Medium mammal		22	-	6,31	4	-	1,93	145		141,16	8	-	4,76
Large mammal		4	-	12,51	36	-	113,19	44		186,98	-	-	-

Table 2. Quantification of the zooarchaeological remains from the Lengyel sites in the cadastre of Kiarov (Slovakia) by taxon, by period.

	Lengyel I									Epi-Lengyel											
	Veľké ortovisko				Šimonovské ortovisko (Features C18, C19)					Šimonovské ortovisko							Nad Kiarovskou pustatinou				
	Sheep/goat	Swine	Cattle/aurochs	Red deer	Sheep/goat	Cattle	Swine	Roe deer	Red deer	Sheep/goat	Cattle	Swine	Cattle/aurochs	Roe deer	Red deer	Red fox	Sheep/goat	Swine	Cattle/aurochs	Roe deer	Red deer
	Ovis/Capra	*Sus domesticus*	*Bos taurus/primigenius*	*Cervus elaphus*	*Ovis/Capra*	*Bos taurus*	*Sus domesticus*	*Capreolus capreolus*	*Cervus elaphus*	*Ovis/Capra*	*Bos taurus*	*Sus domesticus*	*Bos taurus/primigenius*	*Capreolus capreolus*	*Cervus elaphus*	*Vulpes vulpes*	*Ovis/Capra*	*Sus domesticus*	*Bos taurus/primigenius*	*Capreolus capreolus*	*Cervus elaphus*
skull/cranium	-	-	-	-	-	-	-	-	-	7	-	21	-	-	-	-	-	-	-	-	-
os parientale	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-
os zygomaticus	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
dentes	-	5	-	-	-	-	-	-	-	4	5	8	5	1	-	-	-	1	-	-	1
cornu	-	-	-	1	-	-	-	-	-	-	-	-	-	7	1	-	-	-	-	2	-
mandibula	1	-	-	-	-	-	-	-	-	9	-	2	-	-	-	-	-	-	-	-	-
maxilla	-	-	-	-	-	-	2	-	-	-	-	8	15	-	-	-	-	-	-	-	-
costae	1	-	-	-	2	22	5	3	-	45	2	-	17	-	-	-	-	-	2	-	-
scapula	-	-	-	-	6	-	-	-	-	12	2	8	18	3	-	-	1	-	-	-	-
humerus	-	-	-	-	6	1	-	-	3	1	-	-	2	-	-	-	2	-	-	-	-
radius	-	-	-	-	1	2	-	-	1	15	-	-	3	-	-	-	-	-	-	-	-
ulna	-	-	-	-	1	1	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-
os carpale II et III	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
os carpi intermedium	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
os carpi radiale	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-
os carpi ulnare	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
metacarpus I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
metacarpus II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-

Table 3. Quantification of mammal remains from the Lengyel sites in the cadastre of Kiarov (Slovakia) by anatomical element, by period.

	Lengyel I									Epi-Lengyel											
	Veľké ortovisko				Šimonovské ortovisko (Features C18, C19)					Šimonovské ortovisko							Nad Kiarovskou pustatinou				
metacarpus III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
metacarpus IV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
metacarpus V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
metacarpus	-	-	-	-	1	2	-	-	2	5	3	-	-	-	-	-	1	-	-	-	-
pelvis	-	-	-	-	2	-	-	-	2	-	-	2	-	3	-	-	-	-	-	-	-
femur	-	-	-	-	-	7	-	1	-	11	-	3	1	1	-	-	-	-	-	-	-
fibula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
tibia	-	-	-	-	2	2	-	-	-	12	1	2	2	2	1	-	1	-	-	-	-
astragalus	-	-	-	-	-	-	-	-	-	5	1	-	-	-	-	-	-	-	-	-	-
calcaneus	-	-	-	-	2	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
patella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
os centrotarsale	1	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
os tarsale II et III	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
metatarzus II	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
metatarzus III	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4 (f)	-	-	-	-	-
metatarzus V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-
metatarzus	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-
phalanx 1	-	-	1	-	1	-	-	-	-	6	1	-	-	3	-	3	-	-	-	-	-
phalanx 2	-	-	-	-	-	2	-	-	-	3	-	1	-	4	-	-	-	1	-	-	-
phalanx 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
os sacrum	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
vertebra cervicalis	-	-	-	-	-	4	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
vertebra lumbalis	-	-	-	-	-	-	-	-	-	5	-	-	-	1	-	-	-	-	-	-	-
vertebra thoracica	-	-	-	-	-	3	-	2	-	7	-	-	-	2	-	-	-	-	-	-	-
long bone	3	-	-	-	-	-	-	-	-	5	-	-	2	-	-	-	-	-	-	-	-
small bone	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
metapodium	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
vertebrae	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-

Table 3, continued.

	Lengyel I							Epi-Lengyel						
Estimated temperature	Veľké ortovisko			Šimonovské ortovisko (Features C18, C19)			TOTAL	Šimonovské ortovisko						TOTAL
	Ovis/ Capra	Medium mammal	Indet.	*Capreolus capreolus*	Medium mammal	Indet.		*Ovis/ Capra*	*Bos taurus*	*Sus domesticus*	Medium mammal	Large mammal	Indet.	
252-525°C						1	**1**	35	4	1	37	3	12	**92**
525-645°C	1			2			**3**	6			8		2	**16**
645-940°C					1		**1**	2			4	1	1	**8**
>940°C	4	21	1				**26**	5			1	1	14	**21**

Table 4. Quantification of the zooarchaeological remains from the Lengyel sites in Kiarov (Slovakia) by estimated temperature of thermal alteration, by period, by taxon or size category (NISP).

The age at death could be determined for only a single caprine individual; the wear pattern of the teeth of the lower jaw indicates that the animal died at more than 36 months of age.

The animal remains featured no intentional modification (as cutting and chopping). Evidence for heat treatment was observed in 27 fragments, specifically caprine (5), medium mammal (21), and an indeterminate species (1) (Table 4). A single caprine bone was burnt black, which may suggest a temperature of 525-645°C. The other bones, 26 fragments in total, were burnt chalk white, which may suggest temperatures higher than 940°C (Shipman *et al.* 1984; Thurzo and Beňuš 2005).

Kiarov, Šimonovské ortovisko (features C18 and C19)

Two features at the site of Šimonovské ortovisko were dated to the Lengyel I. These features – C18 and C19 – created a small group ca. 30-50 m away from the other Epi-Lengyel features at the site and yielded 223 bone fragments, weighing 1463.87 g in total. Out of these, 124 fragments remained unidentified (indeterminate, small, medium and large mammal) (Table 2). The identified species of domesticated animals are domestic cattle (*Bos taurus*), domestic pig (*Sus domesticus*), and caprines (*Ovis/Capra*). The identified wild game species are roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) and the unionid clams (Unionidae sp.). Items that could only be identified to one of the auxiliary categories – medium and large mammals – and indeterminate fragments were found as well.

Several specimens could be assigned an age at death. A single specimen identified as caprine belonged to an individual that died at 6-10 months of age. Based on the wear of the teeth of the upper jaw, a single domestic pig specimen belonged to an individual that died at the age of 21 months. The age at death of domestic cattle was estimated based on the epiphyseal fusion of two individual femurs. Both specimens belonged to animals that died around 42 months of age. One red deer age died around 42 months of age as well, based on the epiphyseal fusion of its humerus.

Whithers height could only be calculated for a caprine; based on measurement of one of its heel bones (calcaneus), it may have had a withers height of 64 cm.

Antler fragments of both the roe deer and the red deer were lacking. These species were represented mainly by long bone fragments – *i.e.* humerus, radial bone, femur, metacarpal – as well as rib, vertebra and pelvis (Table 3).

The bones featured intentional lesions in the form of cuts found on two domestic cattle bone fragments (a rib and a heel bone).

Singeing is present on 4 bone fragments (Table 4). Brown to brownish black burning suggests a single unidentified bone belonging to an indeterminate species was subjected to temperatures of 252-525°C. Two fragments of a single male roe deer rib bone were burnt blackish grey (525-645°C). A single unidentified medium mammal bone was burnt greyish white (645-940°C) (Shipman *et al.* 1984; Thurzo and Beňuš 2005).

Epi-Lengyel

Kiarov, Šimonovské ortovisko

Of the 840 bone fragments, weighing 3091.37 g in total, found at Šimonovské ortovisko, 452 fragments remain unidentified (auxiliary categories and indeterminate). This site is dated to the Epi-Lengyel (Table 2). The identified species are domestic cattle (*Bos taurus*), domestic pig (*Sus domesticus*), and caprine (*Ovis/Capra*). The identified wild game species are aurochs (*Bos primigenius*), roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), and red fox (*Vulpes vulpes*). Unidentified bird species (*Aves* sp.); helicid snail (Helicidae sp.); roman snail (*Helix pomatia*); white-lipped snail (*Cepaea hortensis*); bones of small, medium-sized and large mammals; and indeterminate bones were found as well.

Age at death could be assigned to several specimens. Two caprine specimens indicate an age of 15-24 months, a third single specimen an age of 23-36 months, and a fourth single specimen an age of 36-42 months. The age of death of the domestic pig was identified for two specimens based on tooth wear and epiphyseal fusion. One was slaughtered at the age of 12 months, the other at the age of 14-24 months. A single roe deer specimen, an antler still attached to the skull, indicates an age at slaughter of 3-4 years. Another antler fragment represents an individual that shed his antlers at the age of 3-4 (note that this is not the age at death, as the individual could have continued living after it shed the antler).

Withers height could only be calculated for caprines, based on a single radial bone (64.7 cm). The heel bone measurement could also be used to calculate the withers height, indicating heights of 74.9. These calculations based on short bones should only be used in cases where long bone measurements are not available because they are not accurate (von den Driesch and Boessneck 1974).

Anatomically, the roe deer is represented by seven antler fragments and the red deer by one antler fragment (Table 3). Two red fox specimens found in Feature 6 are a curiosity, as they all originated in the front and rear limb bones (metacarpal and carpal bones, metatarsal bones and phalanges). This find is interesting from the point of view that the fox is not commonly found in settlements from this period in Slovakia and the anatomical features could indicate that these are remains of fur.

One of the bones featured intentional lesions, in the form of cuts and sanding on a single caprine rib.

Singing is present on 137 fragments (Table 4), of which most (n=92) are burnt brown or brownish black, which suggests they were heated to a temperature of 252-525°C. Black bone colouring (525-645°C) was present on 16 fragments, grey (645-940°C) on 8 fragments, and chalk white (over 940°C) on 21 fragments (Shipman *et al.* 1984; Thurzo and Beňuš 2005).

Some bones featured gnawing marks left by carnivores or rodents. The domestic pig bones featured carnivore tooth marks on a pelvis and a femur and rodent tooth marks on an intermediate phalanx. Other carnivores gnaw marks were found on two long bone diaphysis fragments belonging to the large mammal auxiliary category.

Kiarov, Nad Kiarovskou pustatinou

Among the 19 bone fragments, weighing 76.14 g in total, found at Nad Kiarovskou pustatinou (Table 2), the following taxa and size categories were identified: domestic cattle or aurochs? (*Bos taurus/primigenius*), domestic pig (*Sus domesticus*), and caprine (*Ovis/Capra*). The only wild game species identified was roe deer (*Capreolus capreolus*), based on two fragments of a single antler (Table 3). The medium mammal auxiliary category is also present (n=8).

The age of death could only be determined for a single domestic pig specimen (ca. 12 months).

This assemblage featured no intentional lesions or singing. A single tibia fragment belonging to a caprine featured gnaw marks left by rodents.

Discussion

Three sites within the Kiarov cadastre featured several domestic and wild mammals, as well as several mollusc species. The individual sites (features) dated back to different periods, hence only the settlements which belonged to the Classic Lengyel culture and the Epi-Lengyel period were evaluated.

The Veľké ortovisko site (15 features) and 2 features (C18 and C19) at the Šimonovské ortovisko site were dated into the Classic Lengyel period. In total, 263 bone fragments weighing 1560.92 g belong to this period. The most common identified species was domestic cattle, followed by caprines. This location featured wild game remains, namely red deer and roe deer. It is to be pointed out, however, that fragments pertaining to these two species originated in long bones, pelvis, ribs, and vertebrae, and only one antler fragment was present. Suggesting that this wild game was used mainly as a meat source. Antlers may have been applied to construct tools as well, though this is not verified.

Only the caprines group had an identifiable wither height, based on a single heel bone. It suggests the wither height of 64 cm. Age categories suggest that the caprine was slaughtered at a very young age (juvenis), and pigs as adults (adultus). Domestic cattle and red deer were slaughtered later in their lifecycle (maturus) (Fig. 2). It may be presumed that sheep/goats were bred mostly for meat and perhaps milk, while pigs were raised largely for meat based on the determined age profiles.

Only domestic cattle featured intentional lesions (in this case cuts), namely on a heel bone (calcaneus) and a rib. The bone assemblage dated to the Lengyel I featured 31 burnt bone fragments. The majority (84%) were burnt white, which suggests temperatures higher than 940 °C. These fragments were usually burnt long bone fragments.

Other features at Šimonovské ortovisko and Nad Kiarovskou pustatinou were dated to the Epi-Lengyel. In total, 859 bone fragments weighing 3167,51 g can be dated into this period. The highest number of fragments originate from caprines, followed by domestic cattle or aurochs and domestic pigs.

The state of the fragments allowed for the withers height to be determined only in the case of caprines. The withers height was 64.7 cm (calculated from radial bone), slightly higher than for Lengyel I. We do not, however, consider this difference to be particularly important because it can also result from the calculation of withers using different bones (radial bone *vs.* heel bone). If we compare the withers height calculated based on two identical bones (heel bones), this trend is also confirmed (64.1 cm in Lengyel I *vs.* 74.9 cm in Epi-Lengyel). However, it should be noted that the conclusion is only hypothetical, as it cannot be statistically proven based on two bones. The age at death was determinable only for three specimens (Fig. 3). Three caprine items belonged to the subadult age group, and a single caprine specimen belonged to the adult age group. Only two domestic pig specimens had a determinable age, one being of a subadult, the other of an adult. For pigs, mortality profiles indicate sustained harvesting, starting from the end of the first year and continuing to the third year of life. However, it is important to remember that the osteological sample available is rather small for bigger conclusions. The slaughter of young adult animals is most consistent with a strategy geared towards meat production and the reduction of reproduction. The roe deer age of slaughter was based on an antler attached to a skull and determined to be 3-4 years. Another fragment of a shed roe deer antler suggests 3-4 years of age. This fragment, however, is not an accurate age-at-death indicator, as it could have been harvested as antler drops.

Intentional alterations, namely chop marks and sanding, were present only on a single caprine bone fragment. Apart from those, the bone modification was largely limited to burning, with 16% (n=137) dated to Epi-Lengyel exhibiting charring or

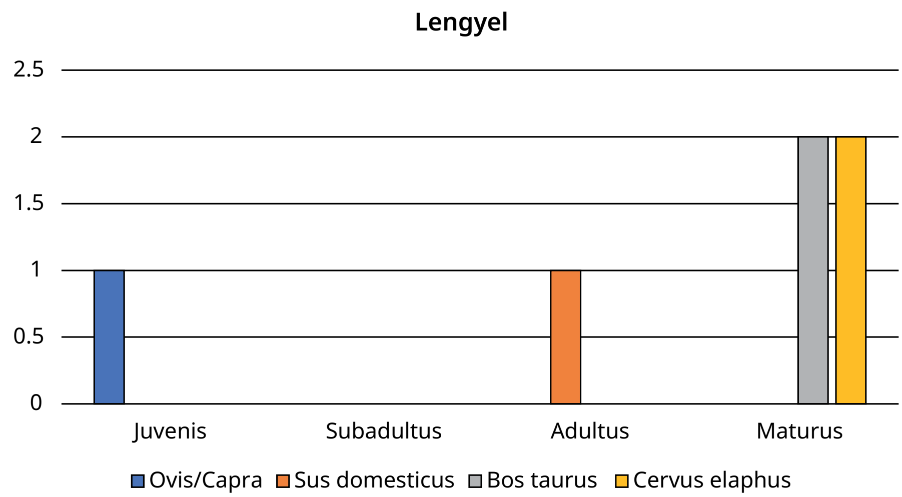


Figure 2. Age representation of animals in the Classic Lengyel culture in Kiarov (based on NISP).

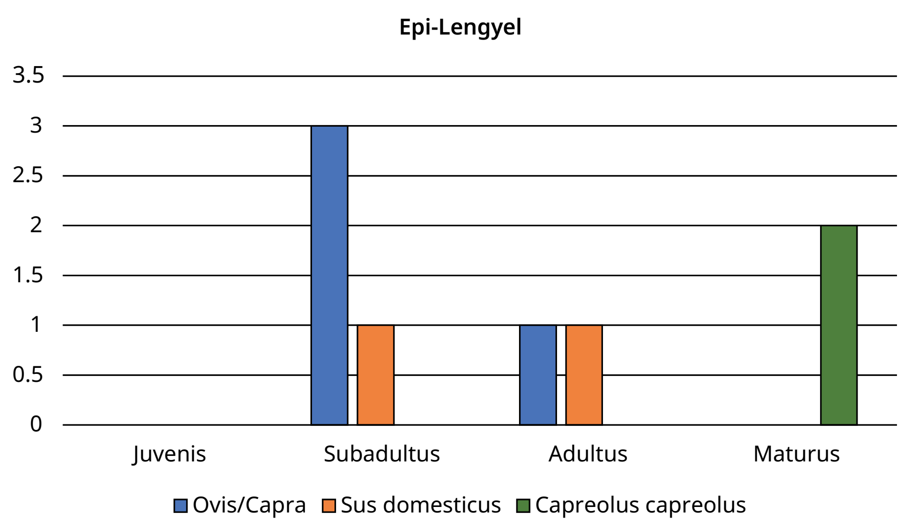


Figure 3. Biological age distribution of mammals from the Epi-Lengyel site in Kiarov (based on number of identified specimens).

calcination. The highest proportion of burnt bones was recorded at Šimonovské ortovisko (75.2%). Most of these bone fragments featured a brownish black colouring, suggesting temperatures of 252-525°C, and most that could be assigned to anatomical element originate from the front and rear limb bones.

The remains of a red fox can be viewed as a special deposit. They were found in the eastern half of Feature 6 on the Šimonovské ortovisko Epi-Lengyel site. This pit featured the bottom parts of three limbs, meaning at least two specimens were present. Curiously, this circular feature with a trapezoid (conical) ground plan and a rounded bottom (1.30 m in length, 1.15 m in width, 0.3 m in depth) featured tiny pieces of copper (slag?) and a clay nozzle (Beljak Pažinová and Beljak 2014, 49, Fig. 44). No other pit on site featured similar finds.

Bone fragmentation, skeletal element distribution and traces of modification document processing and disposal of animal carcasses. At the three Kiarov sites, the distribution of skeletal elements across the settlement shows that body parts represented in proportion to their occurrence in a live animal (Table 3), indicating that domesticated animals were primarily slaughtered on site, as otherwise, the non-flesh-bearing elements would probably have been underrepresented. Charred and calcined bones, which occur in larger quantities at the Epi-Lengyel settlement

of Šimonovské ortovisko, could indicate bones were roasted after meat removal (Shipman *et al.* 1984; Outram 2001; Thurzo and Beňuš 2005). Such a technique would fit several fragments that are only slightly charred and that show a semi-dry-bone fracture pattern, a pattern that can also be achieved by heating (Outram 2001). For the fully calcined bones, it is more likely that they were disposed of in a fire and later taken out with the ash to be deposited in the waste pits.

Chewing marks are not related to the processing of meat, but to waste disposal. Chewing marks from carnivores, as well as, in two cases, rodents were identified in Epi-Lengyel material. The chewed bones suggest that they were left lying in the open for some time before being discarded in the waste pits.

Overall, we can state that the faunal distribution within each settlement varies slightly in terms of the taxonomic and skeletal element representation and the degree of bone fragmentation. In the Classic Lengyel culture, cattle, pigs and caprines are almost equally abundant, whereas in the Epi-Lengyel, caprines dominate. Unfortunately, the sample sizes are too small to confirm whether this is due to specific animal use strategies (economies) or differences in disposal strategies.

The wider picture

In total only 13 sites so far (Fig. 4, Table 5) are known from Slovakia from the period of the Lengyel culture and Epi-Lengyel that have analysed animal bones. Apart from the three sites discussed here, comprehensive analysis of animal bones from Lengyel culture sites has so far only been carried out for Svodín. However, the results of this study are not accessible to the wider public (Moser 2011). Other, published contributions, from other sites, mainly relate to the number of discovered bones, or their skeletal element and taxonomic identification (Ambros 1961, 1986; Fabiš 1995). In some cases, the ratio of domesticated to hunted fauna is also presented (Ambros 1986, 1995; Fabiš 1997), as well as counts of the malacofauna (Cheben *et al.* 2001). Only occasionally the sex and age of individuals, the MNI, and pathology given (Ambros 1986, 1995; Holub 2022). These 13 sites did not yield large assemblages of animal bones, mostly numbering in the hundreds and rarely in the thousands (Bučany, Santovka and Svodín) or the dozens (Lužianky and Nitra-Chrenová). The relatively small size of these samples is the result of poor preservation and inadequate recovery methods.

The Lengyel animal economy was based on the major domesticated taxa: cattle, sheep or goat, and pig. Hunted wild animals played a smaller but still significant role. When comparing and interpreting the assemblages, we therefore compare the mammal taxa that had major economic significance (based on NISP).

There is great variability among the faunal assemblages of domesticated mammals in the 13 sites (Table 5). The Proto-Lengyel sites contain more cattle, followed by pig and sheep and goat. In the Classic Lengyel period, cattle comprise more than 40% (Svodín, Nitriansky Hrádok, Santovka and Kiarov[1]). Cattle dominate also at Epi-Lengyel sites, except at Kiarov (Šimonovské ortovisko, Nad Kiarovskou pustatinou), where sheep and goat together increase significantly compared with the Classic Lengyel Kiarov site. The proportion of pig is around 10% at most Classic Lengyel sites, except for Ružindol-Borová (below 1%), and 15-20% at most Epi-Lengyel sites, except for Nitra-Chrenová (6.5%). Sheep and goat bones are present in greater quantities at Epi-Lengyel sites, often comprising around 20% or more of an assemblage, than on Classic Lengyel sites, where they comprise between 8% and 16% (except for Kiarov1).

1 Kiarov-Veľké ortovisko and Kiarov-Šimonovské ortovisko (features C18 and C19).

	Site	Period	NISP (total/ defined)	Cattle	Pig	Sheep/ goat	Wild mam- mal	Source
1	Bíňa	Proto-Lengyel	115	29 (25.2%)	12 (10.4%)	3 (2.6%)	37 (32%)	Ambros 1986, 13
2	Lužianky	Proto-Lengyel	87/51	38 (74.5%)	3 (5.9%)	2 (3.9%)	3 (5.9%)	Ambros 1961, 85
3	Nitra-Mlynárce	Proto-Lengyel	256/224	131 (58.5%)	34 (15.2%)	24 (10.7%)	33 (15.2%)	Ambros 1961, 85; Ambros 1995
4	Bučany	Lengyel I	2151/2076	352 (16.4%)	231 (10.7%)	-	1355 (65.2%)	Ambros 1986, 13; Ambros 1995
5	Kiarov	Lengyel I	263/112	49 (43.7%)	12 (10.7%)	30 (26.8%)	15 (13.4%)	this study
6	Ružindol-Borová	Lengyel I	407/321	60 (18.7%)	3 (0.9%)	51 (15.9%)	96 (30%)	Fabiš 1997, 171-174
7	Svodín	Lengyel I	12,094/8946	3776 (42.2%)	717 (8%)	645 (7.2%)	3003 (33.6%)	Moser 2011, 22, 23
8	Šurany-Nitriansky Hrádok	Lengyel I	1031	454 (44%)	139 (13.5%)	90 (8.7%)	262 (25.7%)	Ambros 1986, 12, 13; Ambros 1995
9	Santovka	Lengyel I-II	2444/2419	1006 (41.6%)	617 (25.5%)	91 (3.8%)	681 (28.2%)	Ambros 1986, 12, 13; Ambros 1995
10	Jelšovce	Epi-Lengyel	163	64 (39.3%)	33 (20.2%)	30 (18.4%)	15 (9.8 %)	Fabiš 1995, 179-193
11	Kiarov	Epi-Lengyel	859/399	16 (4%)	60 (15%)	184 (46.1%)	59 (14.8%)	this study
12	Nitra-Selenec	Epi-Lengyel	2153/658	269 (40.9%)	130 (19.8%)	155 (23.55%)	25 (3.8%)	Holub 2022, 175-178
13	Nitra-Chrenová	Epi-Lengyel	86/62	55 (88.7%)	4 (6.5%)	-	2 (2%)	Beljak Pažinová et al. 2024, 18-19

Table 5. Mammal taxonomic distribution at Lengyel culture and Epi-Lengyel sites in Slovakia with analysed zooarchaeological material. Column 'specified'=total NISP without indeterminate and auxiliary categories.

The overwhelming reliance on domesticated livestock at Lengyel sites in what is today Slovakia is also consistent with animal exploitation systems employed by Lengyel communities elsewhere in central Europe (*e.g.* Pucher 2004, 2005, 2020; Dreslerová 2006; Bogucki 2008). Cattle remains represent 70-80% of the domesticated mammal remains on Lengyel culture sites in Slovakia. Cattle herding typically served as the primary source of meat, milk, and manure (*e.g.* Bickle and Whittle 2013). In second place in Slovakia terms of NISP is the domestic pig (up to 25%), followed by sheep/goat (3-26%). Changes in animal husbandry likely pertain to climate oscillations, which were fairly common during the Lengyel culture (Baldia 2013, 204-208). Especially the lower number of caprines in some sites (Pucher 2004, 2005) may be connected to climate, as this species does not do best in a cold and wet environment (as noted by Bökönyi 1974). On the other hand, a wet climate is preferred by cattle. Domestic pig has perhaps the most unexacting requirements. The end of the Classic Lengyel culture belongs to what is known as the rapid climate change period, which had a global impact (Mayewsky *et al.* 2004) and significantly affected the economy and the social organisation of the Neolithic people (*i.e.* Čižmář *et al.* 2004; Dreslerová 2012).

Bones of wild ungulates are already present in 'Pre-Lengyel' phases in what is today Slovakia, at Bíňa, Lužianky and Nitra-Mlynárce (Table 5). However, in central Europe, animal osteological material features a significant rise in wild game over domesticated animals at the beginning of the Classic Lengyel culture. Hunted animals represent more than half of the bone finds at Bučany and make up a smaller but still significant share at Svodín, Šurany, Ružindol-Borová and Santovka (Table 5). This trend is also seen in the surrounding Lengyel area, *e.g.* at Těšetice-Kyjovice (45.5%) in Moravia (Fejfar 1975-1976; Kazdová 1984, 231-234); at Aszód (57.3%) in Hungary (Kalicz 1985, 103); and at Unterwölbling (81.8%), Friebritz (53.3%), and Kamegg (44%) in Austria (Pucher 2004, 2020). Exceptional is the site of Ölkam, in Upper Austria, which featured a very high proportion of wild game (90.9%), especially red deer, but also including significant components of wild pig and roe deer, along with some wild cattle (Schmitzberger 2001). This is interpreted as either a short-term situation caused by a sudden loss of livestock (epidemic, plague) or the

result of various armed conflicts, where the settlers wanted to compensate for their loss through hunting (Schmitzberger 2001; Pucher 2004, 381).

This situation in the Lengyel I is generally attributed to socially motivated activities arising in part from the ecological crisis (Pavúk 1991, 355) and involving the construction of rondels (Oliva 2004, 514). Based on the faunal remains, the inhabitants based their economy to a great extent on hunting. In general, this also involved deer, a prestigious hunted animal. However, its importance may be overestimated due to the presence of antlers, which may not have been acquired by hunting. With some exceptions, the proportion of hunted game (Kuča *et al.* 2011) plummets sharply in the later Lengyel phases, as well as in the Epi-Lengyel, and not only in today's Slovakia (Table 5; Podborský 1993, 149).

The proportion of remains relating to hunting at the three settlements in central Slovakia discussed here is little different from that at other Lengyel culture and Epi-Lengyel settlements. The number and proportion of wild ungulate bones in the Classic Lengyel assemblages (Table 5) is non-trivial, as they comprise between 25% and 65% of the sample, except at Kiarov[2] (only 13.4%). The abundance of wild ungulates at Classic Lengyel sites illustrates the level at which it could potentially have been exploited. But this was not the level chosen by the inhabitants of the Kiarov sites, whereas we cannot exclude the reason that these resources were not available in the region.

The low proportions (less than 10%, except for Kiarov) of wild animal bones at the Epi-Lengyel sites are also surprising and must be attributed to human choice. Interesting is the possible hunting of red fox that took place at the Epi-Lengyel site of Kiarov-Šimonovské ortovisko, although it is unclear if this was carried out on an opportunistic basis or as part of intentional decisions to protect agricultural fields. Anyway, the presence of fox bones at Kiarov-Šimonovské ortovisko shows that when a wild animal's death was desired, the effort could be expended to hunt it. The relatively low level of hunting at Epi-Lengyel sites does not contradict the fact that in the forests and fields surrounding the settlements there was a substantial resource base of wild ungulates. For one reason or another, the inhabitants chose not to exploit it more than they did.

Overall, the Lengyel culture animal economies were dominated by domesticated animals, usually amounting to more than 90% of the faunal assemblages in Slovakia. In general, at the Classic Lengyel sites, cattle comprise between 16% and 44% of any given sample, sheep and goat between 3 and 27%, and pig between 1% and 25%. At the Epi-Lengyel sites, cattle comprise between 4% and almost 89%, sheep and goat between 18% and 46%, and pig between 6% and 20%. Does this mean that domesticated livestock were able to satisfy the meat demands of the inhabitants? We can assume that the animal economy of the different livestock species was internally organised and differentiated. The livestock (both pig and ruminants) species were certainly used in a generalised meat-production strategy, with secondary products (ruminants only) a secondary consideration.

In the case of wild ungulates, it appears that they did not supply any resource that could not be obtained from the domesticated livestock or by gathering rather than hunting, so it was not worth the effort to pursue them in any broadly systematic way.

2 Kiarov-Veľké ortovisko and Kiarov-Šimonovské ortovisko (features C18 and C19).

Conclusion

The rescue archaeological research conducted in Kiarov, in central Slovakia, uncovered three sites dating back to the Classic Lengyel and the Epi-Lengyel. These sites – Veľké ortovisko, Šimonovské ortovisko, and Nad Kiarovskou pustatinou – contained animal osteological material, which was analysed in this paper as a case study. In total, the three archaeozoological assemblages contained 1122 bone and shell fragments, totalling ca. 4.7 kg in weight. The results indicate a focus on domesticated livestock, with only occasional hunting of wild ungulates. In the Lengyel I, the highest number of fragments belonged to domestic cattle and caprines. Caprines dominated in numbers in the Epi-Lengyel, followed by domestic pigs. Domesticated mammals were mainly kept for meat production. Caprines and domestic pigs were slaughtered as juveniles as well as adults. Older specimens were identified among the cattle.

In the case of red deer and roe deer, shed antlers were found mainly in the Classic Lengyel culture settlement at Kiarov, which suggests that antlers were being collected. The remains of aurochs and snails were found only at the Epi-Lengyel settlement of Kiarov-Šimonovské ortovisko. This site also featured the lower limb parts of a red fox, all in a single feature. Overall, however, it can be concluded that hunting played a marginal role over the entire Lengyel culture and Epi-Lengyel.

Spatial differences in the faunal distribution at the Kiarov sites may reflect different subsistence decisions and social practices by the Lengyel and Epi-Lengyel populations. The overall picture is of an economy with a balanced portfolio comprised of three major components: cattle, sheep/goat, and pig. Wild herbivores are incidental, perhaps killed opportunistically. Indeed, as noted above, many of the red deer specimens are antlers, while some of the roe deer bones have been selected for tool manufacture and thus are not strictly consumption debris (Beljak Pažinová and Beljak 2014, 53).

The range of animals exploited at the Kiarov sites is similar to that seen at other Lengyel culture and Epi-Lengyel settlements in Slovakia (Table 5). The mammalian taxa that had a major economic role were the four main domesticates (cattle, sheep, goat and pig) and the two most abundant wild herbivore species (red deer and roe deer). Together, these make up more than 85% of the total mammal NISP at the Lengyel sites and more than 80% at the Epi-Lengyel sites. Other mammal species, while still of research interest, are effectively 'noise' in the overall economic system of the Lengyel culture.

Differences in the dominant domesticated species and variation in the proportion of wild animals exploited at various Lengyel sites may be due to different local hunting traditions that persist into the Eneolithic, variation in local ecologies that support different wild taxa, subsistence decisions, and what is referred to as 'cultural preferences' (Döhle 1993; Lüning 2000). The Lengyel culture and Epi-Lengyel settlements (including Kiarov) had diverse regional origins and subsistence practices showing intra-site differences in faunal distribution, but much larger faunal assemblages are needed to explore this. The presence of heterogenous local faunal assemblages should be expected also in the future, and only the study of many contemporaneous samples can give an accurate picture of the regional animal economy.

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References

Adams, B.J. and Crabtree, P.J., 2008. *Comparative skeletal anatomy: a photographic atlas for medical examiners, coroners, forensic anthropologists, and archaeologists*. Totowa: Humana Press.

Ambros, C., 1961. Zvieracie kosti z neolitických objektov z Lužianok a Mlynáriec, okr. Nitra. *Zborník Filozofickej fakulty Univerzity Komenského Musaica*, 12 (2), 81-93.

Ambros, C., 1986. Tierknochenfunde aus der Siedlungen der Lengyel-Kultur in der Slowakei. *In:* B. Chropovský and H. Friesienger, eds. *Internationales Symposium über die Lengyel-Kultur*. Nitra and Wien: Archäologisches Institut der Slowakischen Akademie der Wissenschaften and Institut für Ur- und Frühgeschichte der Universität Wien, 11-17.

Ambros, C., 1995. *Tierreste aus neolithischen und bronzezetlichen Siedlungen in der Slowakei. Archeologický* ústav *Slovenskej akadémie vied Nitra*. Unpublished manuscript.

Baldia, M.O., 2013. Chapter 16. Breaking Unnatural Barriers: Comparative Archaeology, Climate, and Culture Change in central and northern Europe (6100-2700 BC). *In:* M. O. Baldia, T. K. Perttula, D. S. Frink, eds. *Comparative Archaeology and Paleoclimatology. Socio-Cultural responses to a changing world*. BAR International Series 2456. Oxford: BAR Publishing, 175-241.

Barna P, J., 2011. *A lengyeli kultúra kialakulása a DNy-Dunántúlon* [The Formation of the Lengyel culture in Southwestern Transdanubia]. Unpublished PhD dissertation, Eötvös Loránd Tudományegyetem, Budapest.

Barna P., J., 2017. *The formation of the Lengyel culture in south-western Transdanubia*. Budapest: Archaeolingua.

Bartosiewicz, L., 2005. Plain talk: animals, environment and culture in the Neolithic of the Carpathian Basin and adjacent areas. *In:* D. Bailey, A.W.R. Whittle, V. Cummings, eds. *(Un)settling the Neolithic*. Oxford: Oxbow Books, 51-63.

Behrensmeyer, A.K., 1978. Taphonomic and ecologic information from bone weathering. *Paleobiology*, 4, 150-162.

Beljak Pažinová, N. and Beljak, J., 2014. *Archaeological investigation on the high-pressure gas interconnection pipeline SK-HU in 2013: life in early times or the world of prehistoric communities in Kiarov*. Nitra: Archaeological Institute SAS.

Bickle, P. and Whittle, A.W.R., 2013. LBK lifeways: a search for difference. *In:* P. Bickle and A.W.R. Whittle, eds. *The first farmers of central Europe: diversity in LBK lifeways*. Oxford: Oxbow Books, 1-25.

Bogucki, P., 2008. Animal exploitation by the Brze Kujawski Group in the Brześć Kujawski and Osłonki region. *In:* R. Grygiel, ed. *Neolit i Początki Epoki Brązu w Rejonie Brześcia Kujawskiego and Osłonek (The Neolithic and Early Bronze Age in the Brześć Kujawski and Osłonki region).* Volume II/3. Lódź: Konrad Jażdżewski Foundation for Archaeological Research and Museum of Archaeology and Ethnography, 1581-1704.

Bocheński, Z.M. and Tomek, T., 2009a. *A key for the identification of domestic bird bones in Europe: Galliformes and Columbiformes*. Kraków: Institute of Systematics and Evolution of Animals, Polish Academy of Sciences.

Bocheński, Z.M. and Tomek, T., 2009b. *A key for the identification of domestic bird bones in Europe: preliminary determination*. Kraków: Institute of Systematics and Evolution of Animals, Polish Academy of Sciences.

Boessneck, J., 1969. Osteological differences between sheep (Ovis aries Linné) and goat (*Capra hircus* Linné). *In:* D.R. Brothwell and E.S. Higgs, eds. *Science in archaeology: a comprehensive survey of progress and research*. London: Praeger, 311-358.

Bökönyi, S., 1974. *History of domestic mammals in central and eastern Europe*. Budapest: Akadémiai Kiadó.

Cheben, I., Illášová Ľ., Miklíková, Z., 2001. Schránky mäkkýšov v archeologických nálezoch neolitu a eneolitu Slovenská. *In:* M. Metlička, ed. *Otázky neolitu a eneolitu našich zemí – 2000: sborník příspěvků z 19. pracovního setkání badatelů zaměřených na výzkum neolitu a eneolitu* České *a Slovenské republiky Plzeň 9. 12. 10. 2000*. Plzeň: Západočeské Muzeum, 233-237.

Čižmář, Z., Pavúk, J., Procházková, P., Šmíd, M., 2004. K problému definování finálního stadia lengyelské kultúry. *In:* B. Hänsel and E. Studeníková, eds. *Zwischen Karpaten und Ägäis. Gedenkschrift für Viera Němejcová-Pavúková*. Internationale Archäologie. Studia honoraria 21. Rahden: Verlag Marie Leidorf GmbH, 207-230.

Diaconescu, D., 2014. Remarks on the chronology of the Lengyel culture in the western half of the Carpathian Basin based on the analysis of funerary assemblages. *Praehistorische Zeitschrift*, 89 (1), 12-39. DOI: 10.1515/pz-2014-0002

Döhle, H.-J., 1993. Haustierhaltung und Jagd in der Linearbandkeramikein Überblick. *Zeitschrift für Archäologie*, 27 (1), 105-124.

Dreslerová, D., 2006. Vyhodnocení zvířecích kostí z neolitického sídliště Těšetice-Kyjovice (okr. Znojmo, Česká republika). *Archeologické Rozhledy*, 58 (1), 3-32.

Dreslerová, D., 2012. Human response to potential robust climate change around 5500 cal BP in the territory of Bohemia (Czech Republic). *Interdisciplinaria Archaeologica Natural Sciences in Archaeology*, 3 (1), 43-55.

Fabiš, M., 1994. *Analýza zvieracích zvyškov z objektov fortifikácie osady lengyelskej kultúry vo Svodíne*. Manuscript on file, Archeologický ústav SAV, Nitra.

Fabiš, M., 1995. Analyse der Tierknochen aus der Siedlung der Ludanice-Gruppe in Jelšovce. *In:* J. Pavúk and J. Bátora, eds. *Siedlung und Gräber der Ludanice-Gruppe in Jelšovce*. Nitra: Archeologický ústav SAV, 179-194.

Fabiš, M., 1997. Analysis of animal remains. *In:* V. Němejcová-Pavúková, ed. *Kreisgrabenanlage der Lengyel-Kultur in Ružindol-Borová*. Studia Archeaologica et Mediaevalia III. Bratislava: Katedra archeológie FF UK, 171-174.

Fejfar, O., 1975-1976. Rozbor osteologického materiálu z Těšetic-Kyjovic. *Sborník prací Filozofické fakulty brněnské university*, E 20-21, 191-193.

Fock, J., 1966. *Metrische Untersuchungen an Metapodien einiger europäischer Rinderassen*. Unpublished PhD dissertation, Ludwig-Maximilians-Universität, München.

France, D.L., 2009. *Human and nonhuman bone identification: a color atlas*. Boca Raton: CRC Press.

Furholt, M., Bátora, J., Cheben, I., Kroll, H., Rassmann, K., Tóth, P., 2014. Vráble-Veľké Lehemby: eine Siedlungsgruppe der Linearkeramik in der Südwestslowakei. Vorbericht über die Untersuchungen der Jahre 2010 und 2012 und Deutungsansätze. *Slovenská Archeológia*, 62 (2), 227-266.

Furholt, M., Cheben, I., Müller, J., Bistáková, A., Wunderlich, M., Müller-Scheeßel, N. eds., 2020. *Archaeology in the* Žitava *Valley I: the LBK and* Želiezovce *settlement site of Vráble*. Leiden: Sidestone Press.

Gabulová, M., Bistáková, A., Holub, M., Mihályiová, J., Nemergut, A., Cheben, M., Pyżewicz, K., 2022. *Sídlisko ludanickej skupiny* v Nitre-*Chrenovej, poloha Selenec*. Nitra: Archeologický ústav SAV.

Grant, A., 1982. The use of tooth wear as a guide of the age of domestic ungulates. *In:* B. Wilson, C. Grigson, S. Payne, eds. *Ageing and sexing animal bones from archaeological sites*. British Archaeological Reports British Series B109. Oxford: Hands and Walker, 91-108.

Halstead, P. and Collins, P., 1995. *Sheffield animal bone tutorial: taxonomic identification of the principal limb bones of common European farmyard animals and deer: a multimedia tutorial*. Glasgow: Archaeology Consortium, TL TP, University of Glasgow.

Halstead, P., Collins, P., Isaakidou, V., 2002. Sorting the sheep from the goats: morphological distinctions between the mandibles and mandibular teeth of adult

Ovis and Capra. *Journal of Archaeological Science*, 29 (5), 545-553. DOI:10.1006/jasc.2001.0777

Harcourt, R.A., 1974. The dog in prehistoric and early historic Britain. *Journal of Archaeological Science*, 1 (2), 151-175. DOI:10.1016/0305-4403(74)90040-5

Hillson, S., 2005. *Teeth*. Second edition. Cambridge: Cambridge University Press.

Holub, M., 2022. Zvířecí osteologický materiál ze sídliště ludanickej skupiny na lokalitě Nitra-Chrenová, poloha Selenec. *In:* M. Gabulová, ed. *Sídlisko ludanickej skupiny* v Nitre-*Chrenovej, poloha Selenec*. Nitra: Archeologický ústav SAV, 175-187.

Horváth, T., Svingor, E., Molnár, M., 2008. New radiocarbon dates for the Baden culture. *Radiocarbon*, 50 (3), 447-458.

Kalicz, N., 1985. *Kőkori falu Aszódon*. Múzeumi Füzetek 32. Aszód: Petőfi Múzeum.

Kazdová, E., 1984. *Těšetice-Kyjovice 1. Starší stupeň kultúry s moravskou malovanou keramikou*. Brno: Univerzita J. E. Purkyně.

Klein, R.G. and Cruz-Uribe, K., 1984. *The analysis of animal bones from archeological sites*. Chicago and London: University of Chicago Press.

Kobryń, H. and Lasota-Moskalewska, A., 1989. Certain osteometric differences between the aurochs and domestic cattle. *Acta Theriologica*, 34 (4), 67-82.

Kolda, J., 1951. *Osteologický atlas*. Prague Zdravotnické nakladatelství.

Kuča, M., Schenk, Z., Nývltová Fišáková M., 2011. Lengyelské sídliště v Dluhonicích, okr. Přerov a jeho postavení v rámci počátku mladšího stupně lengyelské kultúry v prostoru jižního vstupu Moravské brány. *Acta Musei Moraviae: Scientiae Sociales*, 96 (1), 33-57.

Kyselý, R., 2004. Kvantifikační metody v archeozoologii. *Archeologické Rozhledy*, 56 (2), 279-296.

Lenneis, E., ed., 2017. *Erste Bauerndörferälteste Kultbauten. Die frühe und mittlere Jungsteinzeit in Niederösterreich*. Archäologie Niederösterreichs 1. Wien: Österreichische Akademie der Wissenschaften.

Lüning, J., 2000. *Steinzeitliche Bauern in Deutschland. Die Landwirtschaft im Neolithikum*. Universitätsforschungen zur prähistorischen Archäologie 58. Bonn: Dr. Rudolf Habelt GmbH.

Manning, K., Timpson, A., Colledge, S., Crema, E., Edinborough, K., Kerig, T., Shennan, S., 2014. The chronology of culture: a comparative assessment of European Neolithic dating approaches. *Antiquity*, 88 (342), 1065-1080. DOI:10.1017/S0003598X00115327

Mayewski, P.A., Rohling, E.E., Stager, J.C., Karlén, W., Maasch, K.A., Meeker, L.D., Meyerson, E.A., Gasse, F., van Kreveld, S., Holmgren, K., Lee-Thorp, J., Rosqvist, G., Rack, F., Staubwasser, M., Schneider, R.R., Steig, E.J., 2004. Holocene climate variability. *Quaternary Research*, 62 (3), 243-255. DOI:10.1016/j.yqres.2004.07.001

Moser, D.J., 2011. *Die Tierknochenfunde aus Svodín (Slowakei). Analyse eines neolithischen Inventars mit Fokus auf die tierischen Subsistenzgrundlagen*. PhD dissertation, Philosophische Fakultät der Eberhard Karls Universität, Tübingen.

Oliva, M., 2004. Flint mining, rondels, hillforts: symbolic works or too much free time? *Archeologické Rozhledy*, 56 (3), 499-531.

Oross, K. and Bánffy, E., 2009. Three successive waves of Neolithisation: LBK development in Transdanubia. *Documenta Praehistorica*, 36, 175-189. DOI:10.4312/dp.36.11

Outram, A.K., 2001. A new approach to identifying bone marrow and grease exploitation: why the 'indeterminate' fragments should not be ignored. *Journal of Archaeological Science*, 28 (4), 401-410. DOI:10.1006/jasc.2000.0619

Pavúk, J., 1981. Súčasný stav štúdia lengyelskej kultúry na Slovensku. *Památky Archeologické*, 72, 255-299.

Pavúk, J., 1991. Lengyel-culture fortified settlements in Slovakia. *Antiquity*, 65 (247), 348-357. DOI:10.1017/S0003598X00079850

Pavúk, J., 2000. Das Epilengyel/Lengyel IV als kulturhistorische Einheit. *Slovenská Archeológia*, 48 (1), 1-26.

Pavúk, J., 2007. Zur Frage der Entstehung und Verbreitung der Lengyel-Kultur. *In:* J.K. Kozłowski and P. Raczky, eds. *The Lengyel, Polgár and related cultures in the Middle/Late Neolithic in central Europe*. Kraków: Polish Academy of Art and Sciences, 11-28.

Pavúk, J., 2010. Neuere äneolithische Kupferfunde aus der Westslowakei. *Slovenská Archeológia*, 58 (2), 229-240.

Payne, S., 1973. Kill-off patterns in sheep and goats: the mandibles from Aşvan Kale. *Anatolian Studies*, 23, 281-303. DOI: 10.2307/3642547

Payne, S., 1987. Reference codes for wear states in the mandibular cheek teeth of sheep and goats. *Journal of Archaeological Science*, 14 (6), 609-614. DOI: 10.1016/0305-4403(87)90079-3

Podborský, V., 1993. Nástup zemědělské civilizace. *In:* V. Podborský, ed. *Pravěké dějiny Moravy*. Brno: Muzejní a vlastivědná společnost, 71-152.

Popesko, P., 2007. *Atlas topografickej anatómie hospodárskych zvierat*. Bratislava: Príroda.

Pucher, E., 2004. Der mittelneolithische Tierknochenkomplex von Melk-Winden (Niederösterreich). Annalen des Naturhistorischen Museums Serie A105. Wien: *Naturhistorisches Museum*, 363-403.

Pucher, E., 2005. Tiere und Kreisgrabenanlagen. *In:* F. Daim and W. Neubauer, eds. *Zeitreise Heldenberg. Geheimnisvolle Kreisgräben. Katalog zur Niederösterreichischen Landesausstellung 2005*. Horn and Wien: Berger, 132-137.

Pucher, E., 2020. *Das Tierknochenmaterial aus der mittelneolithischen Kreisgrabenanlage Friebritz-Süd (Niederösterreich). Eine Fallstudie zur Trennung von Ur- und Hausrinderknochen*. BAR International Series 2960. Oxford: BAR.

Regenye, J., Bánffy, E., Demján, P., Ebert, J., Osztás, A., Bronk Ramsey, C., Dunbar, E., Friedrich, R., Bayliss, A., Beavan, N., Gaydarska, B., Whittle, A.W.R., 2020. Narratives for Lengyel funerary practice. *Bericht der Römisch-Germanischen Komission*, 97, 2016, 5-80. DOI: 10.11588/berrgk.2016.0.76630

Reimer P.J., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., …Talamo, S., 2020. The IntCal20 northern hemisphere radiocarbon age calibration curve (0-55 cal kBP). *Radiocarbon*, 62 (4), 725-757.

Reitz, E.J. and Wing, E.S., 2008. *Zooarchaeology*. 2nd edition. Cambridge: Cambridge University Press.

Ruttkay, E., 1995. Spätneolithikum. *In:* E. Lenneis, Chr. Neugebauer-Maresch, E. Ruttkay, eds. *Jungsteinzeit im Osten Österreichs*. Wissenschaftliche Schriftenreihe 102/103/104/105. St. Pölten and Wien: Verlag Niederösterreichisches Pressehaus, 108-158, 178-209.

Schmid, E., 1972. *Atlas of animal bones: for prehistorians, archaeologists and Quaternary geologists*. Amsterdam and London and New York: Elsevier.

Schmitzberger, M., 2001. Die Tierknochen aus der mittelneolithischen Kreisgrabenanlage Ölkam (Oberösterreich). *Jahrbuch des Oberösterreichischer Musealvereines*, 146 (I), 43-86.

Schmitzberger, M., 2009. *Haus- und Jagdtiere im Neolithikum des österreichischen Donauraumes*. PhD dissertation, Universität Wien, Wien.

Shipman, P., Foster, G., Schoeninger, M., 1984. Burnt bones and teeth: an experimental study of color, morphology, crystal structure and shrinkage. *Journal of Archaeological Science*, 11 (4), 307-325. DOI: 10.1016/0305-4403(84)90013-X

Stadler, P. and Ruttkay, E., 2007. Absolute chronology of the Moravian-eastern-Austrian Group (MOG) of the painted pottery (Lengyel-culture) based on new radiocarbon dates from Austria. *In:* J.K. Kozłowski and P. Raczky, eds. *The Lengyel, Polgár and related cultures in the Middle/Late Neolithic in central Europe*. Kraków: Polish Academy of Art and Sciences, 117-146.

Stadler, P., Draxler, S., Friesinger, H., Kutschera, W., Priller, A., Rom, W., Steirer, P., Wild, E.M., 2001. *Absolute chronology for early civilisations in Austria and central Europe using 14C-dating with accelerator mass spectrometry with special results for the absolute chronology of Baden culture*. Studia Danubiana Series Symposia II: Cernavodă III-Boleráz. Bucharest: Institute of Thracology, 541-562.

Stadler, P., Ruttkay, E., Doneus, M., Friesinger, H., Lauermann, E., Kutschera, W., Mateiciucová, I., Neubauer, W., Neugebauer-Maresch, Ch., Trnka, G., Weninger, F., Wild, E.M., 2006. Absolutchronologie der Mährisch-Ostösterreichischen Gruppe (MOG) der bemalten Keramik aufgrund von neuen 14C-Datierungen. *Archäologie Österreichs*, 17 (2), 41-55.

Teichert, M., 1969. Osteometrische Untesuchungen zur Berechnung der Widerristhöhe bei vor- und frühgeschichtlichen Schweinen. *Kühn-Archiv*, 83 (3), 237-292.

Thurzo, M. and Beňuš, R., 2005. *Základy tafonómie hominidov a iných stavovcov*. Bratislava: Univerzita Komenského.

Tóth, P., Demján, P., Griačová, K., 2011. Adaptation of settlement strategies to environmental conditions in southern Slovakia in the Neolithic and Eneolithic. *Documenta Praehistorica*, 38, 307-322. DOI: 10.4312/dp.38.24

Vitt, O., 1952. Lošadi Pazyrykskich kurganov [The horses from the kurgans of Pazyryk]. *Sovetskaja Archeologija*, 16, 163-205.

von den Driesch, A., 1976. *A guide to the measurement of animal bones from archaeological sites*. Peabody Museum Bulletin 1. Cambridge: Peabody Museum Press.

von den Driesch, A. and Boessneck, J., 1974. Kritische Anmerkungen zur Widerristhöhenberechnung aus Längenmaßen vor- und frühgeschichtlicher Tierknochen. *Säugetierkundliche Mitteilungen*, 22, 325-348.

Zoetis, T., Tassinari, M.S., Bagi, C., Walthall, K., Hurtt, M.E., 2003. Species comparison of postnatal bone growth and development. Birth Defects Research Part B: Developmental and Reproductive *Toxicology*, 68 (2), 86-110. DOI: 10.1002/bdrb.10012

Continuity in lithic tool production and raw material use at the Neolithic site of Karancsság, in the North-Hungarian Mountains (Nógrád county, Hungary)

Kata Furholt

Abstract

This paper investigates differences and similarities in raw material use and technological processes between the LBK and the Lengyel periods at the site of Karancsság (Middle and Late Neolithic, 5500/5400-4500/4400 BCE), located in the North-Hungarian Mountains, in order to understand connections and the exchange of items, knowledge, and technology among these mountains, Transdanubia, and the Great Hungarian Plain. The region of the North-Hungarian Mountains is of interest archaeologically because it has seen relatively few Neolithic sites excavated in comparison with the adjacent regions. One of the few Neolithic sites to have been analysed and published from the region thus far is the settlement of Szécsény-Ültetés, which neighbours Karancsság and shows archaeological evidence for a mixed material culture in its lithic raw material use and combined pottery style (Zseliz and Szakálhát) in the 6th millennium BCE.

Keywords: *North-Hungarian Mountains, Neolithic, settlement, chipped stone, obsidian, lithic technology, blade production*

Introduction

The site of Karancsság-Alsó-rétek (hereinafter: Karancsság) is located in the Hungarian county of Nógrád, in the North-Hungarian Mountains, close to the River Danube (Fig. 1). The North-Hungarian Mountains form the southern foothills of the West-Carpathian Mountains and are surrounded by the Cserhát Mountains to the south, the North-Carpathian Mountains to the north, the Ipoly Valley to the west (with the river itself forming the border with Slovakia), and the Zagyva Valley to the east. The site

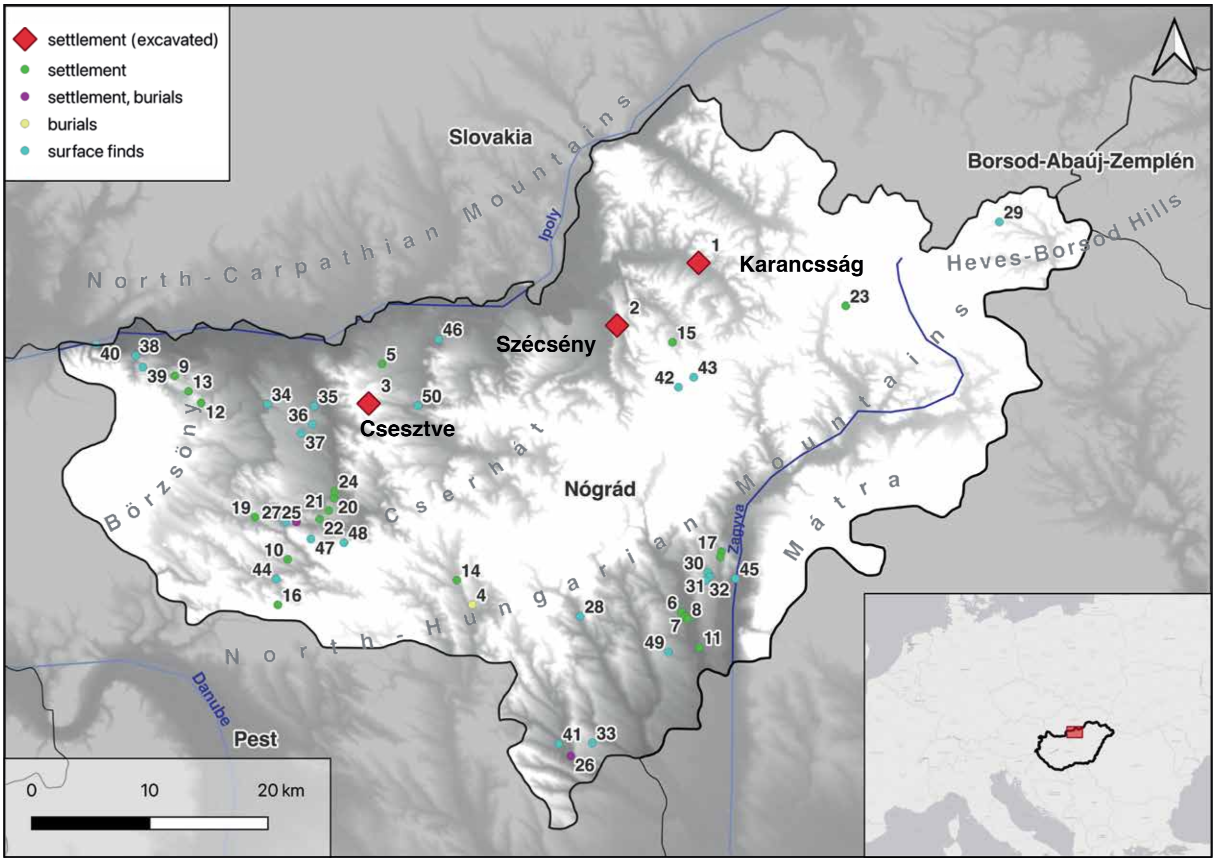

Figure 1. Map showing location of the Neolithic sites in Nógrád county (Hungary) discussed in the text (base map: Esri Shaded Relief https://server.arcgisonline.com/ArcGIS/rest/services/World_Shaded_Relief/MapServer/tile/{z}/{y}/{x}). For site identifiers and information, see Appendix 1.

has some traces of activity dating to the 10th-11th centuries CE, but most of the layers relate to the Middle and the Late Neolithic (5500/5400-4500/4400 BCE). Because of the site's location, the lithics from the site are potentially helpful for studying connections and the exchange of items, knowledge, and technology between and the North-Hungarian Mountains, Transdanubia (western Hungary), and the Alföld (English: Great Hungarian (or Pannonian) Plain).

Compared with that of other counties in Hungary, the inventory of Neolithic sites in Nógrád is comparatively small (ca. 50 are known and even fewer have been excavated), for three main reasons, discussed in more detail below: Nógrád county started to receive scrutiny from Neolithic specialists only relatively recently, it is covered in natural features that impede settlement, and it has a relatively poor economic background and therefore no motorway or major industrial investment that might have led to archaeological excavation.

The Neolithic of the county was first studied by Pál Patay, who stated that the south-western part of the county related to the Linear Pottery culture, or Linearbandkeramik (LBK), and the north-eastern part to the Bükk culture (Patay 1956, 186-187). The next researchers to focus on the area were Viola T. Dobosi and Judit Tárnoki, who excavated the Late Neolithic site of Csesztve-Stalák, publishing the first results, including the lithic material, in 1987 (Dobosi and Tárnoki 1987). Then in the 2010s, the Kubinyi Ferenc Museum, the Hungarian National Museum, the University of Vienna, and the Research Centre for the Humanities of the Hungarian Academy of Science collaborated on the Ipoly-Szécsény Archaeological Program (ISzAP) (principal investigator: Szilvia Fábián), aimed at studying inter-regional trade networks and cultural exchange along the Ipoly Valley, through the LBK site of Szécsény-Ültetés and its surroundings (the Nógrád Hills and the northern part of the Cserhát Mountains) (Fábián *et al.* 2016).

The vast majority of Nógrád county is mountainous and hilly. It is bordered by the Börzsöny Mountains in the west, the Mátra Mountains in the south-east, the Heves-Borsod Hills in the east, and the Karancs-Medves Mountains in the north. The central part of the county is covered by the ranges of the Cserhát Mountains, which gradually flatten towards the north and south.

Nógrád county has seen a lack of economic investment, both historically and recently. This means that there has been very little construction and associated rescue excavation in the last few years.

Karancsság is significant not just because it provides an opportunity to obtain precise stratigraphic data from a period that is relatively poorly known, but also because the findings can be related to those from the complex interdisciplinary research project at Szécsény-Ültetés (Bácsmegi 2014; Fábián *et al.* 2016).

The excavation

The site of Karancsság-Alsó-rétek was excavated between April and July 2002, in advance of construction work, under the direction of Gábor Bácsmegi. The site is situated on a north-south hill slope and adjacent depression that are part of the Litke-Etes Hills (Láng 1967, 311-316; Dövényi 2010, 702-705), in the southern part of the modern-day village of Karancsság, on a lower terrace on the north bank of the Ménes stream. The trenches were positioned south of Road 22, on the higher part of the hill, overtop of the former settlement surface. Although the eastern, southern and western limits of the Neolithic settlement were identifiable, the original extent of the site could not be determined, as the northern end of the site is located under Road 22 (Bácsmegi 2014, 6) (Fig. 2).

Although the site had been subject to ploughing, this had not disturbed the cultural layers, and although the excavation was a salvage project and therefore subject to time constraints relating to the planned construction work. The site thus provided a good opportunity for geoarchaeological and environmental-archaeological investigations, which the field director undertook as part of their PhD research. Bácsmegi focused on the anthropogenic changes that had taken place in this area, thus allowing modelling of the environmental transformations brought about by humans along the Ménes stream (Bácsmegi 2014).

Three trenches were opened, the first two (Trenches 1 and 2) measuring 4 × 5 × 2 m and the third (Trench 3) measuring 4 × 2 × 2 m. Trenches 1 and 2 were excavated stratigraphically, and all the features and finds were documented by cultural layer, while Trench 3 was a control section excavated using the 'shovel-tracking' method that is traditionally used in Hungarian archaeology (separating the archaeological material by artificial levels, 20-25 cm thick) (Bácsmegi 2014, 24, 33) (Fig. 2).

A total of eight stratigraphic layers were distinguished, and these could be grouped into four cultural periods. Layers 1-3 date to the 10th-11th centuries CE (and are hence excluded from the current analysis). Layers 4-5 are associated with the Late Neolithic Lengyel community, which in this region is dated between 5000/4900 and 4500/4400 BCE (Bánffy 1995; Hertelendi *et al.* 1995, 1997; Zalai-Gaál 2007; Yerkes *et al.* 2009; Zalai-Gaál *et al.* 2014; Bánffy *et al.* 2016). Layers 6-7 are associated with the Zseliz LBK community. Layers 8-9 are associated with the LBK, specifically the early phase of the Music Notes (German: Notenkopf) group of the Transdanubian LBK (Bácsmegi 2003, 82). Note that in Hungary, both the Zseliz and the LBK period are considered Middle Neolithic, while in Slovakia, as in central and western Europe, the LBK period (including Zseliz) is considered Early Neolithic (Pavúk 2007). The absolute dates for the LBK period are 5500/5400-5000/4900 BCE (Csengeri 2013; Jakucs *et al.* 2016; Oross *et al.* 2016; Meadows *et al.* 2019; Staniuk *et al.* 2020).

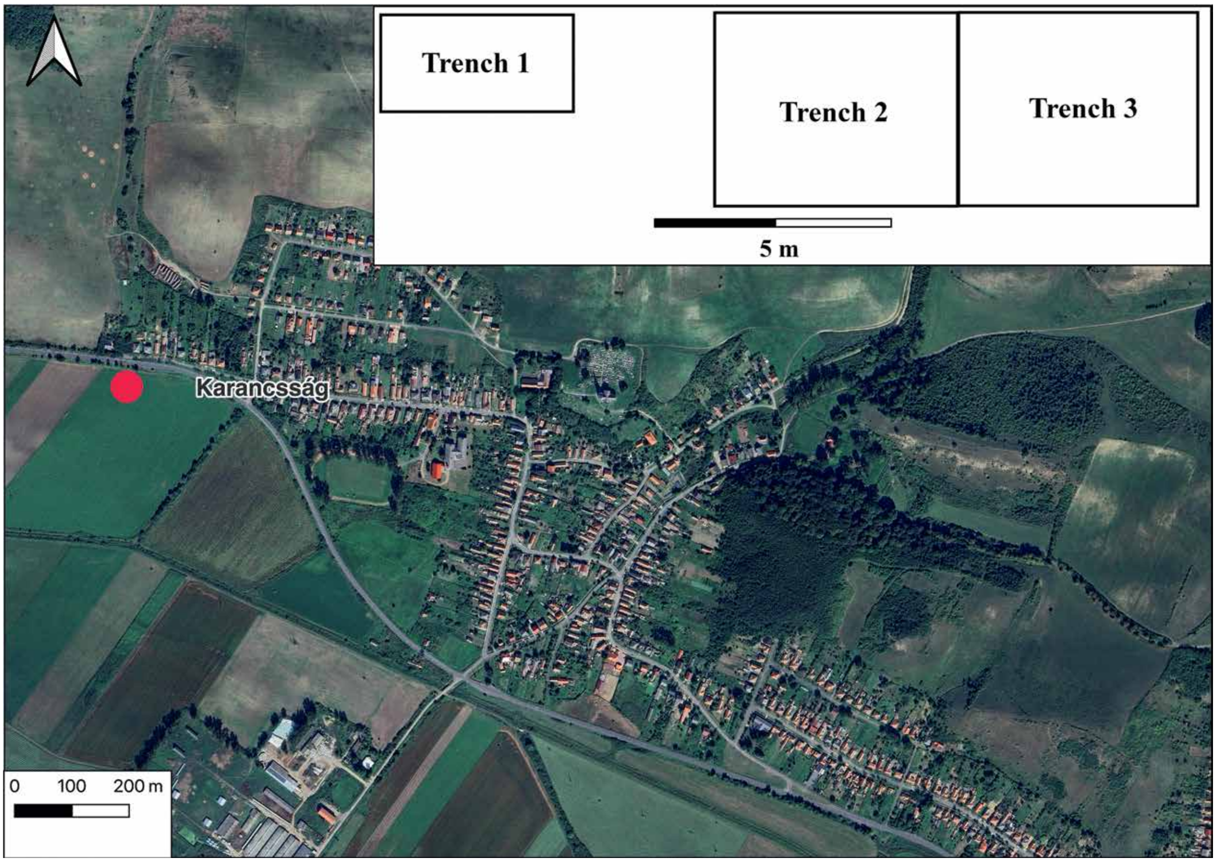

Figure 2. Arial photo showing location of the site of Karancsság (Nógrád county, Hungary) (base map: Google Satellite https://mt1.google.com/vt/lyrs=s&x={x}&y={y}&z={z}) and schematic showing the size of the excavation trenches in relation to each other (inset) (after Bácsmegi 2014, 33, Fig. 11).

Two burials were discovered in Layer 5: Grave 1 contained four pottery vessels and Grave 2 contained one wild boar tusk in addition to the inhumation. Based on the grave goods and the burial practice, Bácsmegi associated them with the Lengyel communities (Bácsmegi 2003, 81-82). Grave 1 was oriented SE – NW and Grave 2 NW – SE, and both orientations are very similar to those of the Lengyel burials at Aszód-Papi földek (Kalicz 1985, 36-41; Siklósi 2013, 60-68). Bácsmegi suggested that these graves are contemporaneous with the early phase of the Aszód, Csabdi and Zengővárkony graveyards and the third construction period at Ižkovce and Svodín, both of which have evidence for rondel settlement and burials (Bácsmegi 2003, 82). Few stone tools were recovered from the archaeological features (in this case, settlement pits); most were recovered from cultural layers. Unfortunately, there are no absolute dates for Karancsság; the dating of the site therefore relies on radiometric dates for the Neolithic of this region, as well as relative dates based on the classical typochronological system, which in turn is based on decorated pottery.

The chipped stone

The number of pieces of chipped stone relating to the Neolithic correlates with the volume of the trench. Trench 1 contained 267 pieces of lithic, Trench 2 contained 260, and Trench 3 contained 115, for a total of 642. Those from Layers 1-3 (n=31) are excluded from the analysis because these layers post-date the Neolithic by millennia and because the priority of this work was to study and compare the material in the sealed cultural layers (Szilágyi 2009) (Table 1). The number of chipped stones recovered from Trenches 1 and 2, where items could be tied to discrete cultural layers, is very similar per layer and per period. For methodological reasons, I will merge the materials of Trenches 1 and 2 by period – LBK (Layers 6-8) and Lengyel

	Trench 1	Trench 2	Trench 3	Total	Ratio (%)
Layers 1-3	10	21	0	31	4.83
Layers 4-5	142	160	0	302	47.04
Layers 6-8	115	79	0	194	30.22
Total	267	260	115	642	
Ratio (%)	41.59	40.50	17.91	100.00	

Table 1. Karancsság (Nógrád county, Hungary). Number of chipped stone items by trench, by layer.

(Layers 4-5) – for the purpose of analysis and focus on comparing the stone items from units relating to the LBK community with those from the Lengyel community. Of the 496 pieces of chipped stone from Layers 4-8 in Trenches 1 and 2, 194 (30.22%) belong to the LBK period and 302 pieces (47.04%) to the Lengyel period. The entire dataset of the chipped stone assemblage, including the technological details, is available on Zenodo.org (Furholt 2024).

Raw materials

All in all, I identified 15 raw material types in the lithic assemblage. I grouped six of them into an overarching category, to help clarify the role of imported raw materials, and I have termed this 'supra-regional lithic raw material'. I was unable to identify the original mountain range or geological formation for some items of chert and radiolarite, and I have termed these 'unsourced chert' or 'unsourced radiolarite'. Items in these two categories represent only a minor proportion of the total number of items compared with the Bakony radiolarite, hydroquartzite and Mátraháza-Felnémet opal. I was unable to identify even the basic raw material of some items, mostly cortex fragments or extremely burnt pieces, and I have termed these 'unidentified'.

The most of the chipped stone items are made on obsidian, an excellent knapping material often called volcanic glass, representing more than 50% in both periods and constituting the most commonly represented lithic raw material. Most of the obsidian is of the Carpathian 1 (Slovakian) type, which is covered with a thin, coarse cortex. The items made on this type of obsidian are transparent and dark grey in colour. The primary geological source of this obsidian, which is well known and well published, is the southerly regions of the Tokaj-Eperjes Mountains (Prešovsko-Tokajské Pohoří) (Biró 1981, 2004, 2014, 2018; Szepesi *et al.* 2018). The second most commonly represented lithic raw material is limnic silicite, which is represented in approximately one quarter of the LBK (24.23%) and Lengyel (23.18%) assemblages. In recent years, it has become the norm in Hungarian research to describe lake-sedimentary siliciclastic rocks – previously known as limnoquartzite in both the archaeological and the geological literature (Biró 1998, 34-35, 2010; Markó 2005; Götze 2010; Szekszárdi *et al.* 2010) – as limnic silicite (Mester and Faragó 2016). The variety of colours and patterns seen in the silicites has resulted in differences between the geological and the archaeological terminology. Silicites include chert, flint, hornstone, spiculite, radiolarite, lydite and lake-sedimentary siliciclastics, and the main characteristic of these silicites is that they contain an extremely large number of microfossils (Přichystal 2010, 177). In the case of Karancsság, I use the term limnic silicite for those lithics that have a light pastel colour (usually in yellowish hues), have a white banded pattern, and contain fossilised plant remains. In general, these limnic silicates have a homogeneous fabric, which made them a good raw material for knapping (Fig. 3, Table 2). Based on the geological literature, lithics from the other Neolithic as well as Palaeolithic sites, and the Comparative Raw Material Collection (Litotheca) of the Hungarian National Museum, this limnic silicite can be seen as a local limnic silicite, which has geological sources in the

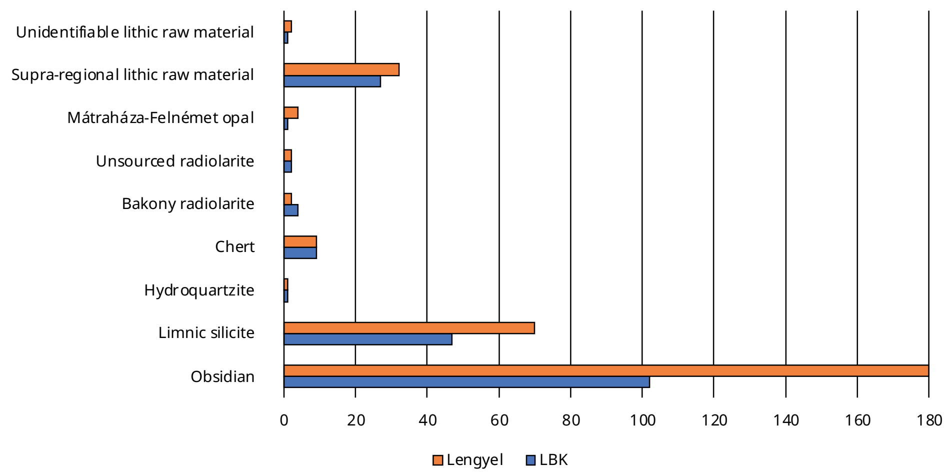

Figure 3. Karancsság (Nógrád county, Hungary). Distribution of lithic raw materials by period.

Table 2. Karancsság (Nógrád county, Hungary). Number and proportion of chipped stone items by raw material, by period.

	LBK		Lengyel	
Raw material	Quantity	Ratio (%)	Quantity	Ratio (%)
Obsidian	102	52.58	180	59.60
Limnic silicite	47	24.23	70	23.18
Hydroquartzite	1	0.52	1	0.33
Chert	9	4.64	9	2.98
Bakony radiolarite	4	2.06	2	0.66
Unsourced radiolarite	2	1.03	2	0.66
Mátraháza-Felnémet opal	1	0.52	4	1.32
Supra-regional lithic raw material ('Imported raw material')	27	13.92	32	10.60
Unidentifiable lithic raw material	1	0.52	2	0.66
Total	194	100.00	302	100.00

Cserhát Mountains (Biró and Dobosi 1991; Biró *et al.* 2000; Markó 2005; Péntek and Zandler 2014; Péntek 2021).

The category supra-regional lithic raw material comprises Cracow Jurassic flint, Carpathian radiolarite, Chocolate flint, Moravian flint, Volhynian flint (these six types are related to northern erratic flint varieties), and Balkan flint. Although the proportion the lithics from distant sources is similar in both periods (14% and 11%), there are some differences in which specific types are present. Cracow Jurassic flint is the most represented northern erratic material in the LBK and Lengyel communities. In the Middle Neolithic (LBK), one or two pieces each of Moravian flint, Volhynian flint, and Balkan flint are present, but in the Late Neolithic (Lengyel) these three types of exotic raw material are absent. In the Late Neolithic (Lengyel), Carpathian radiolarite and Chocolate flint are present in small proportions (Table 3).

Technological and typological characteristics

In order to detect tool production as a process (*chaîne opératoire*), I used technological categories as analytical units, based on the book by Marie-Luise Inizan and colleagues (1999); the monograph by Inna Mateiciucová (2008), which is widely used

	LBK		Lengyel	
Supra-regional raw material	Quantity	Ratio (%)	Quantity	Ratio (%)
Cracow Jurassic flint	23	85.19	27	84.38
Carpathian radiolarite	0	0.00	1	3.13
Chocolate flint	0	0.00	4	12.50
Moravian flint	1	3.70	0	0.00
Volhynian flint	2	7.41	0	0.00
Balkan flint	1	3.70	0	0.00
Total	27	100.00	32	100.00

Table 3. Karancsság (Nógrád county, Hungary). Number and proportion of chipped stone items of supra-regional raw materials by period.

	LBK		Lengyel	
Technological category	Quantity	Ratio (%)	Quantity	Ratio (%)
Core	9	6.70	14	4.64
Raw material fragment	3	1.55	3	0.99
Flake	79	38.66	111	36.75
Blade	90	46.39	156	51.66
Tool	13	6.70	18	5.96
Total	194	100.00	302	100.00

Table 4. Karancsság (Nógrád county, Hungary). Number and proportion of lithic technological categories by period.

	LBK		Lengyel	
Tool type	Quantity	Ratio (%)	Quantity	Ratio (%)
Indeterminate scraper	2	15.38	1	5.56
End-scraper on blade	9	69.23	10	55.56
Side-scraper	0	0.00	2	11.11
Borer	1	7.69	5	27.78
Trapeze	1	7.69	0	0.00
Total	13	100.00	18	100.00

Table 5. Karancsság (Nógrád county, Hungary). Number and proportion of lithic tool types by period.

in Europe; and publications on LBK and Lengyel lithics (Bácskay and Biró 1984; Kaczanowska 1986, 1994, 2001, 2003; Bácskay 1989, 1990; Kaczanowska *et al.* 1993; Marton 2000; Cheben and Illášová 2002; Kaczanowska and Kozłowski 2008, 2013; Szilasi 2009; Allard 2018; Cheben *et al.* 2020; Cheben and Cheben 2021; Allard and Denis 2022).

As was the case for the overarching raw material categories, the ratios of the different technological categories are very similar across the LBK and Lengyel periods. Here, the overarching category 'tools' comprises all artefacts that were created with final retouching and have the modified morphology of a specific tool type, for instance, the curved distal end of an end-scraper on blade or the pointy distal end of a borer (Table 5). Both communities preferred blade debitage and blade-based tools, *e.g.* end-scraper on blades, borers made on blade support, truncated blades, and trapezes. Blades constitute approximately half of the chipped stone assemblage of both the LBK (46.39%) and the Lengyel (51.66%) communities

(Table 4). The proportion of cores and raw material fragments, and especially the high portion of flakes, indicate that the entire tool production process happened inside the settlement.

Lithics of the LBK period

All nine pieces of core attributable to the LBK occupation of the site are of limnic silicite or obsidian and have two or more striking platforms, except for two obsidian cores that are unipolar (*i.e.* the prismatic form of a core with a single striking platform) (Plate 2.20 and 2.22). Most of the cores reflect an economical use of raw material, in the sense that the Neolithic knappers used the original form of the nodule or raw material fragment and tried to use a more or less flat surface to create a blade debitage surface, without any striking platform (Plate 3.24). Some of the cores have suitably prepared striking platforms, which are represented by the facetted talon of the blades, and some of the cores have rejuvenation flakes. Most of the cores with renewed striking platforms are obsidian. In the category flakes, both decortication, rejuvenation, unretouched, and retouched flakes are present (Plate 2.21 and 2.23). The 12 pieces of decortication flake recovered were created during the core preparation phase and can be considered production waste, while the 8 pieces of rejuvenation flake are by-products of the renewal of the core's striking platform. The low proportion of retouched items is typical of the entire LBK lithic assemblage and is also reflected in the presence of only a single retouched flake and seven truncated flakes in the LBK material. The predominance of unretouched items is also characteristic of the blade group: of the 90 pieces of blade, 71 are unretouched and only 19 have any trace of final retouching (Plate 1.6-11). Around 20% of the flakes and blades have cortex on the dorsal surface. The butt types of the blades are quite diverse: cortical, plain, dihedral, facetted, linear, punctiform and winged are all present, but the facetted and the plain butt types dominate. All in all, 23 blades are truncated, mostly on the proximal and the distal ends, and 19 blades are retouched – 11 on the left edge, 6 on the right edge, and 2 on the distal end. On half of the retouched items, the retouch is partial. On the other half, it is continuous. The position of the retouching is mostly inverse (created from the dorsal surface), direct (created from the ventral surface), or alternating and alternate (Inizan *et al.* 1999, 87). Alternating and alternate retouch is not very typical in the Karancsság material. The angle of the retouching is in the majority of cases abrupt or semi-abrupt, and in some cases low. All in all, 56 blades are intact and 34 are fragmentary. Of the latter, 15 have breaks at both ends, 10 only on the distal end, 8 only on the proximal end, and 1 on the mesial part. The majority of the blades have one or two arrises; just nine of them possess three or four arrises. This, together with the fact that there is evidence of only a single knapping accident, supports not only the idea that experienced knappers were responsible for the tool production activity (Inizan *et al.* 1999, 71-73; Shott and Nelson 2008, 30), but also the statement often made in the literature, that by removing two arrises blades and creating two further arrises on the blade debitage surface, the knapper was able to keep a balance with the number of arrises and thus achieve longer blade series removals (or, rather, as many as possible). Altogether 26 blades show use-wear traces macroscopically: in 6 of these, gloss is visible on the edges of the blades (in 5 it is triangle shaped and in 1 it is parallel with the edge) (Plate 1.11 and 1.14).

Lithics of the Lengyel period

The lithics of the Lengyel community show very similar characteristics to those of the LBK community, in that than half of the assemblage are blades and the process of tool production is reconstructable, with the presence of cores, different kinds of flakes and blades, and retouched tools. Except for one unipolar obsidian blade core (Plate 6.31), all the cores have two or more debitage surfaces. Some cores – mostly of obsidian – have

deliberately prepared striking platforms, but the vast majority of the cores have no striking platform (Plate 7.36-40). The Late Neolithic knappers used one removal negative on the edge for achieving removals, concentrated on the natural shape of the core, and used the angles for creating debitage surfaces (Plates 6.34, 7.35-36 and 7.38). Four cores have cortex remaining, indicating that the shaping of the core started from the natural nodules, pebbles, or raw material block forms. Of the flakes, 38% (n=42) have cortex remaining, and a significant number of cortical butts show the early core preparation phase. Besides the cortical type, facetted, plain, dihedral, punctiform, and winged butt types are also represented in the material. Four flakes are truncated on the proximal end, and four flakes are retouched, two of them on the proximal end, one on the distal end, and one on the left edge. The retouching was done from the ventral site, and the angles are abrupt or semi-abrupt. Only six flakes have any knapping accidents; most of these resulted in hinged flakes, and one resulted in a plunging flake (Plate 5.27-29) (Inizan *et al.* 1999, 34). Of the blades, 27% (n=42) have remaining cortex, but just three butts are cortical. The majority of the butts are of the facetted and plain types, and some are of the dihedral, linear, punctiform and winged types. A total of 21 blades are truncated on one or both ends. The number of arrises is similar to the LBK period: one (48 pieces) and two (65 pieces) arrises are typical, and three and four arrises are less typical. All in all, 33 blades have use-wear traces detectable with the naked eye, mostly on the edges. Of the 156 blades, 18 are retouched on one or both edges, mostly from the dorsal side, with an abrupt or semi-abrupt retouch angle (Plate 4.11 and 4.12). There are four pieces with evidence for a knapping accident, in the form of two plunging blades, a tongue break, and a hinged blade. Six blades have gloss traces on the edges, three of them parallel with the edges and three triangular (Plate 5.24 and 5.25). Microscopic use-wear analysis has not yet been undertaken. It may be possible through microscopic use-wear analysis to determine whether these blades were used as sickle inserts.

Correlation of raw materials and technological categories

The ratios of raw materials and technological categories, as well as the principles of tool production, are very similar across the LBK and Lengyel periods. To further investigate the communities' technological habits, I compared raw materials and technological categories in order to study the potential debitage concept. Table 6 shows all the lithic data, whereas Fig. 4 shows only those raw materials represented by more than 10 pieces, for ease of presentation. Obsidian dominates among the cores, flakes and blades in both the LBK and Lengyel periods. The only difference between the two periods in the obsidian is that there are the four obsidian tools in the Lengyel layers (two end-scrapers on blade, one borer, and one side-scraper), because there are no obsidian tools in the LBK material (Plate 4.13-18). Only the tools on obsidian and limnic silicite evidence the entire process of tool production, showing both the early core preparation phase and the further blade removals. All of the raw material fragments are limnic silicite, which means, from a technological point of view, that the knappers tried to create a core, but because of the inhomogeneity of fabric, only a few removals occurred on these pieces (Plate 6.33). Only a small difference is detectable between the two periods with respect to limnic silicite use, namely in the number and types of tools. While five scrapers (four end-scrapers on blades and one indeterminate scraper) were recovered for the Lengyel period, six end-scrapers on blades, one indeterminate scraper, one borer and one trapeze made from limnic silicite were recovered for the LBK period (Plate 1.10-15). There are no cores or raw material fragments of chert, mostly just flakes and blades. Three chert tools date to the Lengyel period, and all of them were created from burnt chert and on a blade support (two are borers and one and end-scraper on blade). With the exception of one Chocolate flint blade core, there are no cores or raw material fragments from supra-regional raw material, only flakes, blades, and a total of 10 tools (Plate 7.40).

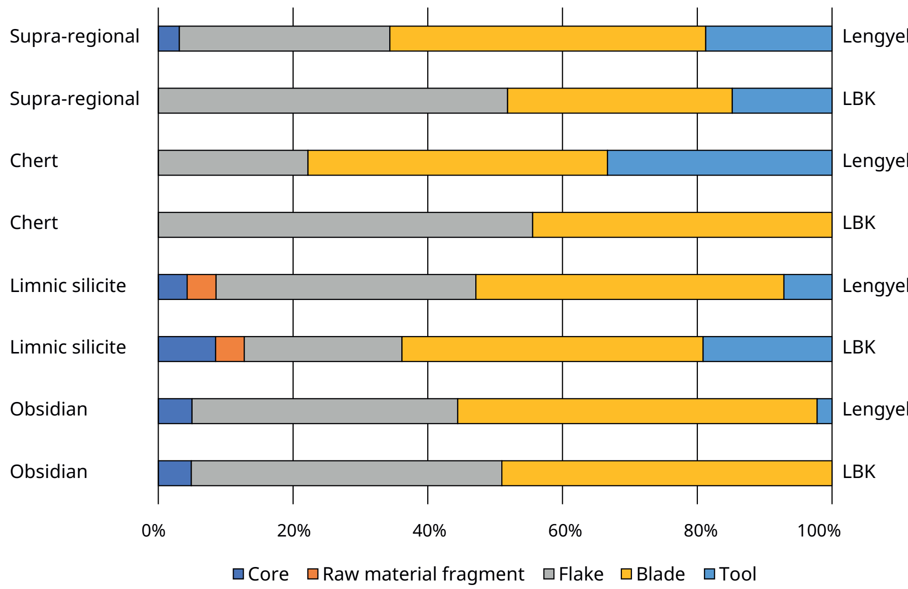

Figure 4. Karancsság (Nógrád county, Hungary). Lithic technological categories by raw material category, with indication of the dominant period of the raw material.

These 10 tools made from supra-regional raw materials represent 32% of the tool category for both periods combined. Four are related to the LBK and six to the Lengyel period. All four LBK tools are end-scrapers on blades, two made from Volhynian flint and two from Cracow Jurassic flint. The Lengyel material comprises three Cracow Jurassic flint end-scrapers on blades, one Chocolate flint side-scraper and two Cracow Jurassic flint borers on blade support. Typically the smaller proportion of supra-regional materials was used for tool production and also reshaped or modified into a secondary or even tertiary tool. In contrast, the local raw materials and the tools made on them did not undergo such high levels of reworking and were more likely to become waste without having seen much use. The LBK material comprises Moravian flint and Balkan flint blades and Volhynian flint end-scrapers on blades, and the Lengyel material comprises Chocolate flint and Cracow Jurassic flint fashioned into end-scrapers on blades, side-scrapers and borers. Among the long-distance raw materials, Cracow Jurassic flint was found in large quantities and was used to make a wide variety of tools in both periods. We can assume that this flint was brought into the settlement as pre-core forms and that the inhabitants removed the blade series and retouched the different tools (Table 7).

Tool production activity

For both periods, the tool production activity can be separated into three main phases: shaping, formatting/debitage and retouching. Viewing the biography of a lithic artefact from a holistic perspective, we can add two additional phases: usage and discard or resharpening and reuse, for a total of five phases (Kopytoff 1986; Gosden and Marshall 1999; van Gijn 2010, 23-34; Joyce 2015). For obsidian and limnic silicite, it is possible to reconstruct the entire process of tool production, and for this reason, we can view Karancsság as a workshop (lithic production) settlement for those two raw materials (Table 8). The presence of cores, raw material fragments and large quantities of flakes as the main technological categories indicates that tool production from these two raw materials was primarily focused on blade production. The entire process is easy to follow with regard to the obsidian because the evidence for working and other traces (*e.g.* knapping accidents, gloss, use-wear traces) is better visible on obsidian than on other materials.

	Obsidian		Limnic silicite		Chert		Supra-regional lithic raw material		Bakony radiolarite		Unsourced radiolarite		Mátraháza-Felnémet opal		Hydroquartzite		Unidentifiable lithic raw material		Total
	LBK	Lengyel	LBK	Lengyel	LBK	Lengyel	LBK	Lengyel	LBK	Lengyel	LBK	Lengyel	LBK	Lengyel	LBK	Lengyel	LBK	Lengyel	
Core	5	9	4	3	0	0	0	1	0	0	0	0	0	0	0	1	0	0	23
Raw material fragment	0	0	2	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	6
Flake	47	71	11	27	5	2	14	10	2	1	0	0	0	0	0	0	0	0	190
Blade	50	96	21	32	4	4	9	15	2	1	1	2	1	4	0	0	1	2	245
Tool	0	4	9	5	0	3	4	6	0	0	0	0	0	0	1	0	0	0	32
Subtotal	102	180	47	70	9	9	27	32	4	2	2	2	1	4	1	1	1	2	496
Total	282	117	18	59	6	4	5	2	3	496									

Table 6. Karancsság (Nógrád county, Hungary). Number of lithic items by raw material, by period, by technological category.

Supra-regional raw material	Technological category					Total	Period
	Core	Raw material fragment	Flake	Blade	Tool		
Cracow Jurassic flint	0	0	13	8	2	23	LBK
	0	0	9	13	5	27	Lengyel
Carpathian radiolarite	0	0	0	0	0	0	LBK
	0	0	1	0	0	1	Lengyel
Chocolate flint	0	0	0	0	0	0	LBK
	1	0	0	2	1	4	Lengyel
Moravian flint	0	0	1	0	0	1	LBK
	0	0	0	0	0	0	Lengyel
Volhynian flint	0	0	0	0	2	2	LBK
	0	0	0	0	0	0	Lengyel
Balkan flint	0	0	0	1	0	1	LBK
	0	0	0	0	0	0	Lengyel
Total	1	0	24	24	10	59	

Table 7. Karancsság (Nógrád county, Hungary). Number of lithic items of supra-regional raw material by technological category, by material, by period.

	Shaping			Formatting/Debitage			Retouching		Usage	
Raw material/Tool making phase and technological feature	decor-tication flake	raw material fragment/ nodules	core	rejuvena-tion flake	unretou-ched flake	unretou-ched blade	retouched flakes, blades	tools	gloss	use-wear trace
Obsidian	+	+	+	+	+	+	+	+	+	+
Limnic silicite	+	+	+	+	+	+	+	+	+	+
Hydroquartzite	-	-	+	-	-	-	+	+	+	+
Chert	-	-	-	+	+	+	+	+	-	+
Bakony radiolarite	-	-	-	-	+	+	-	-	-	+
Unsourced radiolarite	-	+	-	-	-	+	+	-	-	-
Mátraháza-Felnémet opal	-	-	-	-	-	+	-	-	-	+
Cracow Jurassic flint	-	-	-	+	+	+	+	+	+	+
Carpathian radiolarite	-	-	-	-	+	-	-	-	-	-
Chocolate flint	-	-	+	-	-	+	-	+	-	-
Moravian flint	-	-	-	-	-	-	+	-	+	-
Volhynian flint	-	-	-	-	-	-	-	+	+	-
Balkan flint	-	-	-	-	-	+	-	-	-	-

Table 8. Karancsság (Nógrád county, Hungary). Phases of tool production and use activity by raw material.

To reconstruct tool production at Karancsság, I will focus on 1) the presence of cortex and its removal strategy compared with the butt types, which can indicate the nature of the preparation phase and how the knapper(s) used the raw material, both outside and inside the settlement; and 2) the specific blade debitage of obsidian, which provides an opportunity to study the knapping philosophy behind the Karancsság assemblage.

The study of butt types and the cortex on the dorsal face of flakes and blades shows that the knappers used flake removal in the decortication phase and focused on blade removal once the debitage surface had been prepared (Allard 2018; Allard and Denis 2022). In the LBK period, the butts of both flakes and blades are mostly

plain and facetted, whereas in the Lengyel period, the flakes show a higher ratio of cortical butts and cortex than do the blades. This prompts the following questions: Was there is difference in the concept of debitage between the two periods, or were the pre-core form and decortication phases performed outside of the settlement in the LBK period? With the obsidian, the presence of cortex and the cortical butts indicates that all the decortication and pre-core preparation happened inside the settlement. In other words, obsidian nodules came into the settlement in their original form, with cortex, and the entire tool production process took place inside the settlement. But with the local limnic silicite, the lack of evidence for the decortication phase indicates that the pre-core shaping process happened outside of the settlement. This suggests that the early phases of the production process relating to obsidian and limnic silicite differed. The knappers themselves organised procurement of the limnic silicite and had direct access to the original geological sources, where they created the pre-cores or at least performed the decortication removals. In the case of obsidian, the nodules with cortex indicate that the communities of Karancsság obtained this raw material indirectly, through an obsidian circulation/exchange system.

The dominance of obsidian as a raw material and the high degree of technological knowledge evident its working, such as frequently renewed striking platforms of the cores (Plate 2.21), a technological behaviour not present in the case of other raw materials, suggests that this raw material required a greater investment of energy during blade debitage, in order to create a uniformly shaped, very thin series of blades series. The most frequent talon type is the facetted one, and the number of arrises is two in the vast majority of the blades. The Neolithic knappers thus avoided the accumulation of the arrisses, as such an accumulation could have caused trouble during the blade removal process (Kaczanowska and Kozłowski 2008; Allard *et al.* 2017). There are three possible explanations for these facts. The first is techno-economic. It posits that the supply of obsidian was not very frequent or continuous, either because the knappers went direct to the original raw material sources and were only seldom able to travel there or because they relied on other people to transport or exchange the obsidian and were only seldom able to encounter them, in both cases causing the knappers to try to maximise their use of the obsidian. The second is aesthetic. It posits that transparent material is very rare in nature and that especially the C1, Slovakian type of obsidian is can almost appear like glass if the blade is very thin. The third relates to skill and knowledge. It posits that the Neolithic knappers possessed such high levels of skill and knowledge that they were able to spend more time and energy preparing the entire blade removal series, enabling them to remove the maximum number of blades, producing as little waste as possible. In this third explanation, it was the experienced knappers who had access to this high-quality raw material, as supported by the fact that knapping accidents are very rare in this assemblage. The skill and knowledge aspects are related to the technological basis, and the indirect percussion technique was used for the first time in central Europe during the LBK period (Allard *et al.* 2017).

Conclusion

The characteristics of lithic procurement of the Middle and Late Neolithic communities represented by the studied assemblage are reflected in the spectrum of raw materials used, which represent the territory to the east of Karancsság. The lithic production activities demonstrate the technological behaviour and the typical toolkit, which is clearly rooted in the LBK and Lengyel blade production tradition, but the proportion of retouched items seems lower than in other com-

parable assemblages from Transdanubia. Although the Karancsság communities belonged to Transdanubia in terms of their technological knowledge and cultural roots, they preferred to use raw materials from the North-Hungarian Mountains, which were outside their local or familiar area. The geographic position of the site is favourable in that it places it at the intersection of Transdanubia, the Northern Mountain Range, the Gödöllő Hills and the southern part of the North-Carpathian Mountains region.

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References

Allard, P., 2018. Acquisition and circulation of flint materials in the Linear Pottery culture of the Seine Basin. *In:* D.H. Werra and M. Woźny, eds. *Between History and Archaeology: Papers in honour of Jacek Lech*. Archaeopress, 165-172.

Allard, P. and Denis, S., 2022. Technical traditions and individual variability in the Early Neolithic: Linear Pottery culture flint knappers in the Aisne Valley (France). *PLoS One*, 17 (6), e0268442.

Allard, P., Klaric, L. and Hromadová, B., 2017. Obsidian blade debitage at Kašov-Čepegov I (Bükk culture), Slovakia. *Bulgarian e-Journal of Archaeology*, 7, 17-35.

Bácskay, E., 1989. A lengyeli kultúra néhány DK-dunántúli lelőhelyének pattintott kőeszközei [Chipped stone implements in some localities of Lengyel culture in SE-Transdanubia]. *Communicationes Archaeologicae Hungariae*, 5-21.

Bácskay, E., 1990. A lengyeli kultúra pattintott kőeszközei a DK-Dunántúlon II [The chipped stone industry of Lengyel culture in south-east Transdanubia II]. *Communicationes Archaeologicae Hungariae*, 59-66.

Bácskay, E. and Biró T., K., 1984. A lengyeli lelőhely pattintott kőeszközeiről [About the chipped stone tools of Lengyel sites]. *A Béri Balogh Ádám Múzeum Évkönyve*, 12, 43-67.

Bácsmegi, G., 2003. A lengyeli kultúra temetkezései Karancsságon [Die Bestattungen der Lengyel-Kultur in Karancsság]. *Móra Ferenc Múzeum Évkönyvei*, *Studia Archaeologica*, IX, 81-86.

Bácsmegi, G., 2014. *Geoarceológiai* és *környezettörténeti kutatások Karancsság-Alsó-rétek lelőhelyen [Geoarcheological and environmental historical studies on the Karancsság-Alsó-rétek site]*. Unpublished PhD dissertation (in Hungarian, with English summary), Szegedi Tudományegyetem, Szeged.

Bánffy, E., 1995. Über den Ausklug der Lengyel-Kultur in Transdanubia. *In:* T. Kovács, ed. *Neuere Daten zur Siedlungsgeschichte und Chronologie der Kupferzeit des Karpatenbeckens*. Budapest: Magyar Nemzeti Múzeum, 11-28.

Bánffy, E., Osztás, A., Oross, K., Zalai-Gaál, I., Marton, T., Nyerges, É.Á., Köhler, K., Bayliss, A., Hamilton, D. and Whittle, A.W.R., 2016. The Alsónyék story:

towards the history of a persistent place. *Bericht der Römisch-Germanischen Kommission*, 94 2013 (2016), 283-318.

Biró, T.K., 1981. A Kárpát-medencei obszidiánok vizsgálata [Investigation of obsidian from the Carpathian Basin]. *Archaeologiai Értesítő*, 108, 196-205.

Biró, T.K., 1998. *Lithic implements and the circulation of the raw materials in the Great Hungarian Plain during the Late Neolithic Period*. Budapest: Magyar Nemzeti Múzeum.

Biró, T.K., 2004. A kárpáti obszidiánok: legenda és valóság [The Carpathian obsidians: legend and reality]. *Archeometriai Műhely*, 1 (1), 3-8.

Biró, T.K., 2010. Terminological practice for siliceous rocks in Hungary from petroarchaeological point of view. *Archeometriai Műhely*, 7 (3), 195-202.

Biró, T.K., 2014. Carpathian obsidians: state of art. *In:* M. Yamada and A. Ono, eds. *Lithic raw material exploitation and circulation in prehistory: a comparative perspective in diverse palaeoenvironments*. Liège: Université de Liège, Service de préhistoire & Centre de recherches archéologiques, 47-68.

Biró, T.K., 2018. More on the state of art of Hungarian obsidians. *Archeometriai Műhely*, XV (3), 213-224.

Biró, T.K. and Dobosi, T.V., 1991. *Litotheca – Comparative Raw Material Collection of the Hungarian National Museum: catalogue*. Budapest: Hungarian National Museum.

Biró, T.K., Dobosi, T.V. and Schléder, Zs., 2000. *Litotheca II – Comparative Raw Material Collection of the Hungarian National Museum 1990-1997: catalogue*. Budapest: Hungarian National Museum.

Cheben, I. and Illášová, Ľ., 2002. Chipped industry made of limnoquarzite from Žiarska kotlina hollow. *In:* I. Cheben and I. Kuzma, eds. *Otázky neolitu a eneolitu našich krajín – 2001*. Nitra: Archeologický ústav SAV, 105-112.

Cheben, M. and Cheben, I., 2021. Analysis of chipped industry from the settlement of the Želizovce Group in Bajč. *Študijné zvesti Archeologického* ústavu *SAV*, (2), 175-198.

Cheben, M., Hrselová, P., Wunderlich, M. and Szilágyi, K., 2020. Stone tools from the LBK and Želiezovce settlement site of Vráble. *In:* M. Furholt, I. Cheben, J. Müller, A. Bistáková, M. Wunderlich, and Müller-Scheeßel, N., eds. *Archaeology in the* Žitava *Valley I: the LBK and* Želiezovce *settlement site of Vráble*. Leiden: Sidestone Press, 363-416.

Csengeri, P., 2013. *Az alföldi vonaldíszes kerámia kultúrájának késői csoportjai* Északkelet-Magyarországon. *(Az* újabb *kutatások eredményei Borsod – Abaúj – Zemplén megyében) [Late groups of the Alföld Linerar Pottery culture in north-eastern Hungary (new results of the research in Borsod-Abaúj-Zemplén county)]*. Unpublished PhD dissertation (in Hungarian, with English summary), Eötvös Loránd Tudományegyetem, Budapest.

Dobosi, T.V. and Tárnoki, J., 1987. Excavations on Csesztve-Stalák. *Communicationes Archaeologicae Hungariae*, 40, 5-14.

Dövényi, Z., ed., 2010. *Magyarország kistájainak katasztere* [Inventory of Microregions in Hungary]. Budapest: MTA Földrajztudományi Kutatóintézet.

Fábián, Sz., Salisbury, R.B., Serlegi, G., Larsson, N., Guba, Sz. and Bácsmegi, G., 2016. Early settlement and trade in the Ipoly region: introducting the Ipoly-Szécsény Archaeological Project. *Hungarian Archaeology E-Journal*, 2 (spring), 1-10.

Furholt, K., 2024. Dataset of the chipped stone assemblage of the Neolithic Karancsság site (Nógrád county, Hungary) [Dataset]. *Zenodo*. DOI: 10.5281/zenodo.10846717

van Gijn, A.L., 2010. *Flint in focus: lithic biographies in the Neolithic and Bronze Age*. Leiden: Sidestone Press.

Gosden, C. and Marshall, Y., 1999. The cultural biography of objects. *World Archaeology*, 31 (2), 169-178.

Götze, J., 2010. Origin, mineralogy, nomenclature and provenance of silica and SiO2 rocks. *Archeometriai Műhely*, 7 (3), 163-176.

Hertelendi, E., Kalicz, N., Raczky, P., Horváth, F., Veres, M., Svingor, É., Futó, I. and Bartosiewicz, L., 1995. Re-evaluation of the Neolithic in eastern Hungary based on calibrated radiocarbon dates. *Radiocarbon*, 37 (2), 239-244.

Hertelendi, E., Svingor, É., Raczky, P., Horváth, F., Futó, I. and Bartosiewicz, L., 1997. Duration of tell settlements at four prehistoric sites in Hungary. *Radiocarbon*, 40 (2), 659-665.

Inizan, M., Reduron-Ballinger, M., Roche, H. and Tixier, J., 1999. *Technology and terminology of knapped stone*. Nanterre: Cercle de Recherches et d'Etudes Prehistoriques.

Jakucs, J., Bánffy, E., Oross, K., Voicsek, V., Ramsey, C.B., Dunbar, E., Kromer, B., Bayliss, A., Hofmann, D., Marshall, P. and Whittle, A.W.R., 2016. Between the Vinča and Linearbandkeramik worlds: the diversity of practices and identities in the 54th-53rd centuries cal BC in southwest Hungary and beyond. *Journal of World Prehistory*, 29 (3), 267-336.

Joyce, R.A. and Gillespie, S.D., 2015. Making things out of objects that move. *In:* R. Joyce and S.D. Gillespie, eds. *Things in motion: object itineraries in anthropological practice*. Santa Fe: SAR Press.

Kaczanowska, M., 1986. Aus den Studien die Feuersteinindustrie der Lengyel-Kultur. *Béri Balogh* Ádám *Múzeum Évkönyve*, 13, 323-337.

Kaczanowska, M., 1994. Erwägungen über die Spaltindustrie aus Štúrovo. *In:* J. Pavúk, ed. Štúrovo. *Ein Siedlungsplatz der Kultur mit Linearbandkeramik und der* Želiezovce-*Gruppe*. Nitra, 115-119.

Kaczanowska, M., 2001. Feuersteinindustrie des westlichen und östlichen Kreises der Linearbandkeramikkultur – ein Vergleichsversuch. *In:* R. Kertész and J. Makkay, eds. *From the Mesolithic to the Neolithic: Proceedings of the International Archaeological Conference held in the Damjanich Museum of Szolnok, September 22-27, 1996*. Budapest: Archaeolingua, 215-223.

Kaczanowska, M., 2003. Distribution of raw materials used in the chipped stone industry in the western Linien Band Pottery culture and the eastern Linien Band Pottery culture in the Circum-Carpathian Basin. *In:* L. Burnez-Lanotte, ed. *Production and management of lithic materials in the European Lininenbandkeramik*. Oxford: Hadrian Books, 5-10.

Kaczanowska, M. and Kozłowski, J.K., 2008. The Körös and the early eastern Linear culture in the northern part of the Carpathian Basin: a view from the perspective of lithic industries. *In:* S. A. Luca, ed. *The Carpathian Basin and its role in the Neolithisation of the Balkan Peninsula*. Acta Terrae Septemcastrensis VII, 9-38.

Kaczanowska, M. and Kozłowski, J.K., 2013. The transition from the Neolithic to the Copper Age lithic industries in the northern Carpathian Basin. *In:* A. Anders, G. Kalla, V. Kiss, G. Kulcsár, and G. Szabó V., eds. *Moments in time: papers presented to Pál Raczky on his 60th birthday*. Budapest: L'Harmattan, 353-364.

Kaczanowska, M., Kozłowski, J.K. and Šiška, S., 1993. *Neolithic and Eneolithic chipped stone industries from* Šarišské *Michal'any, eastern Slovakia: Linear Pottery, Bükk and Baden cultures*. Kraków: Institute of Archaeology, Jagellonian University, Kraków.

Kalicz, N., 1985. *Kőkori falu Aszódon* [A Neolithic village in Aszód] (in Hungarian, with German summary). Aszód: Petőfi Múzeum.

Kopytoff, I., 1986. The cultural biography of things: commoditization as process. *In:* A. Appadurai, ed. *The social life of things: commodities in cultural perspective*. Cambridge: Cambridge University Press, 64-94.

Láng, S., 1967. *A Cserhát természeti földrajza [Natural geography of the Cserhát]*. Budapest: Akadémiai Kiadó.

Markó, A., 2005. Limnokvarcit a Cserhát hegységben [Limnoquartzite in the Cserhát Mountains]. *Archeometriai Műhely*, 2 (4), 52-55.

Marton, T., 2000. Pattintott kőeszközök Tömördről [Chipped stones from Tömörd]. *In:* Ilon G., ed. *Pannicvlvs B/5*. Szombathely: Pannicvlvs Régiségtani Egylet, 73-100.

Mateiciucová, I., 2008. *Talking stones: the chipped stone industry in Lower Austria and Moravia and the beginnings of the Neolithic in central Europe (LBK), 5700-4900 BC*. Brno: Mazarykova univerzita.

Meadows, J., Müller-Scheeßel, N., Cheben, I., Agerskov Rose, H. and Furholt, M., 2019. Temporal dynamics of Linearbandkeramik houses and settlements, and their implications for detecting the environmental impact of early farming. *The Holocene*, 29 (10). DOI: 10.1177/0959683619857239

Mester, Zs. and Faragó, N., 2016. Prehistoric exploitation of limnosilicites in northern Hungary: problems and perspectives. *Archaeologia Polona*, 54, 33-50.

Oross, K., Osztás, A., Marton, T., Köhler, K., Gallina, Zs., Somogyi, K., Bánffy, E., Bronk Ramsey, C., Goslar, T. and Hamilton, D., 2016. Longhouse times: dating the Alsónyék LBK settlement. *Bericht der Römisch-Germanischen Kommission*, 94 2013(2016), 123-150.

Patay, P., 1956. Újabb kőkori és kelta leletek Nógrádkövesden és a nógrádi dombvidéken [Late Neolithic and Celtic finds at Nógrádkövesd and in the Nógrád Hills]. *Archaeologiai Értesítő*, 83 (2), 186-191.

Pavúk, J., 2007. Zur Frage der Entstehung und Verbreitung der Lengyel-Kultur. *In:* J.K. Kozłowski and P. Raczky, eds. *The Lengyel, Polgár and related cultures in the Middle/Late Neolithic in central Europe*. Budapest and Kraków: The Polish Academy of Arts and Sciences and Eötvös Loránd University, Institute of Archaeological Sciences, 11-28.

Péntek, A., 2021. Utilization of some non-flint lithic raw materials in the Palaeolithic in the Cserhát Mountains and the Galga Valley (northern Hungary). *Archeometriai Műhely*, XVIII (1), 1-26.

Péntek, A. and Zandler, K., 2014. Buják-Szente, egy nyílt színi paleolitikus telep [Buják-Szente, an open-air Palaeolithic site]. *Litikum: Journal of the Lithic Research Roundtable*, 2, 3-16.

Přichystal, A., 2010. Classification of lithic raw material used for prehistoric chipped stone artefacts in general and siliceous sediments (silicites) in particular: the Czech-proposal. *Archeometriai Műhely*, 12 (3), 177-181.

Shott, M.J. and Nelson, M.C., 2008. Lithic reduction, its measurement, and implications: comments on the volume. *In:* W.Jr. Andrefsky, ed. *Lithic technology: measures of production, use, and curation*. Cambridge: Cambridge University Press, 23-45.

Siklósi, Zs., 2013. *Traces of social inequality during the Late Neolithic in the eastern Carpathian Basin*. Budapest: Eötvös Loránd University, Institute of Archaeological Sciences, L'Harmattan.

Staniuk, R., Wunderlich, M., Meadows, J., Müller-Scheeßel, N., Furholt, M. and Cheben, I., 2020. Radiocarbon dating at the LBK and Želizovce settlement site of Vráble. *In:* M. Furholt, I. Cheben, J. Müller, A. Bistáková, M. Wunderlich, and N. Müller-Scheeßel, eds. *Archaeology in the* Žitava *Valley I: the LBK and* Želiezovce *settlement site of Vráble*. Leiden: Sidestone Press, 249-264.

Szekszárdi, A., Szakmány, Gy. and Biró T., K., 2010. Tokaji-hegységi limnokvarcit-limnoopalit nyersanyagok és pattintott kőeszközök archaeometriai vizsgálata I.: Földtani viszonyok, petrográfia [Archaeometric analysis on limnic-quartzite limnic opalite raw materials and chipped stone tools: Tokaj Mts: NE-Hungary I: Geological settings, Petrography]. *Archeometriai Műhely*, 12 (1), 1-18.

Szepesi, J., Lukács, R., Biró T., K., Markó, A., Pécskay, Z. and Harangi, Sz., 2018. Geology of Tokaj Mountains obsidians. *Archeometriai Műhely*, XV (3), 167-180.

Szilágyi, K., 2009. *Karancsság-Alsó-rétek lelőhely középső* és *késő neolit pattintott kőeszközei*. Unpublished bachelor's thesis. Szegedi Tudományegyetem, Szeged.

Szilasi, A.B., 2009. Techno-typological evaluation of the chipped stone implements from the prehistoric settlement at Szombathely-Parkerdő Apartment Complex: preliminary report on the chipped stone implements from Feature 276. *In:* L. Bende and G. Lőrinczy, eds. *Medinától etéig : tisztelgő* írások *Csalog* József *születésének 100.* évfordulóján. *A Csalog* József *Emlékkonferencián, Szentes 2008, október 8 – 10, elhangzott előadások jegyzetekkel* és *irodalmi hivatkozásokkal ellátott változatai*. Szentes: Móra Ferenc Múzeum, 231-238.

Yerkes, R.W., Gyucha, A. and Parkinson, W.A., 2009. A multiscalar approach to modeling the end of the Neolithic on the Great Hungarian Plain using calibrated radiocarbon dates. *Radiocarbon*, 51 (3), 1071-1109.

Zalai-Gaál, I., 2007. Zengővárkony-Svodín-Friebritz. Zu den chronologischen Beziehungen zwischen den territorialen Gruppen der Lengyel-Kultur aufgrund der Gräberfeldanalyse. *In:* J.K. Kozłowski and P. Raczky, eds. *The Lengyel, Polgár and related cultures in the Middle/Late Neolithic in central Europe*. Budapest, Kraków: The Polish Academy of Arts and Sciences Kraków, Eötvös Loránd University Institute of Archaeological Sciences, 147-184.

Zalai-Gaál, I., Osztás, A. and Somogyi, K., 2014. Zur relativen Chronologie der Lengyel-Kultur im westlichen Karpatenbecken. Präliminarien zur Bayesischen Analyse. *Acta Archaeologica Academiae Scientierum Hungaricae*, 65, 285-334.

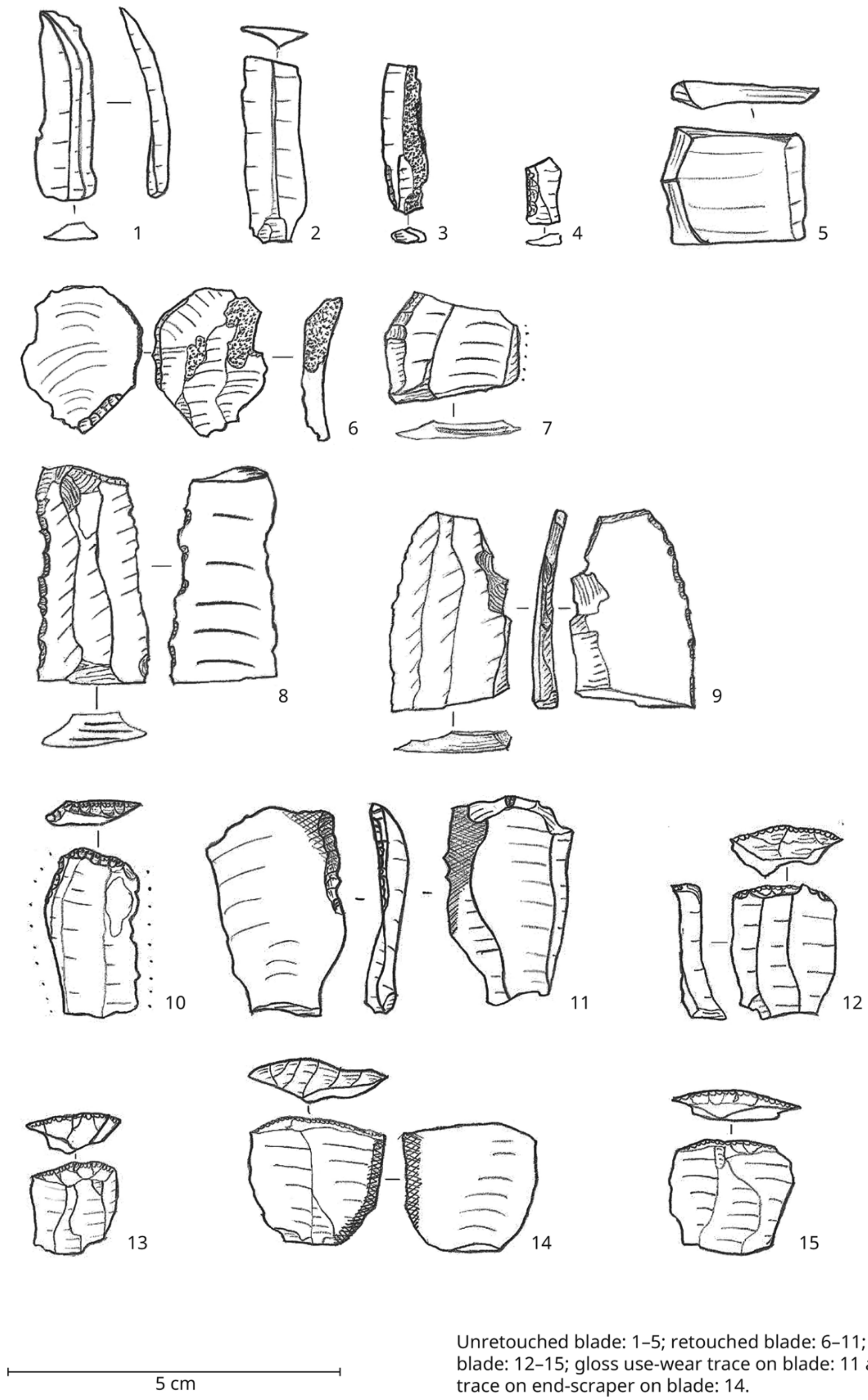

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Plate 1. Karancsság (Nógrád county, Hungary). Lithic items from the LBK period.

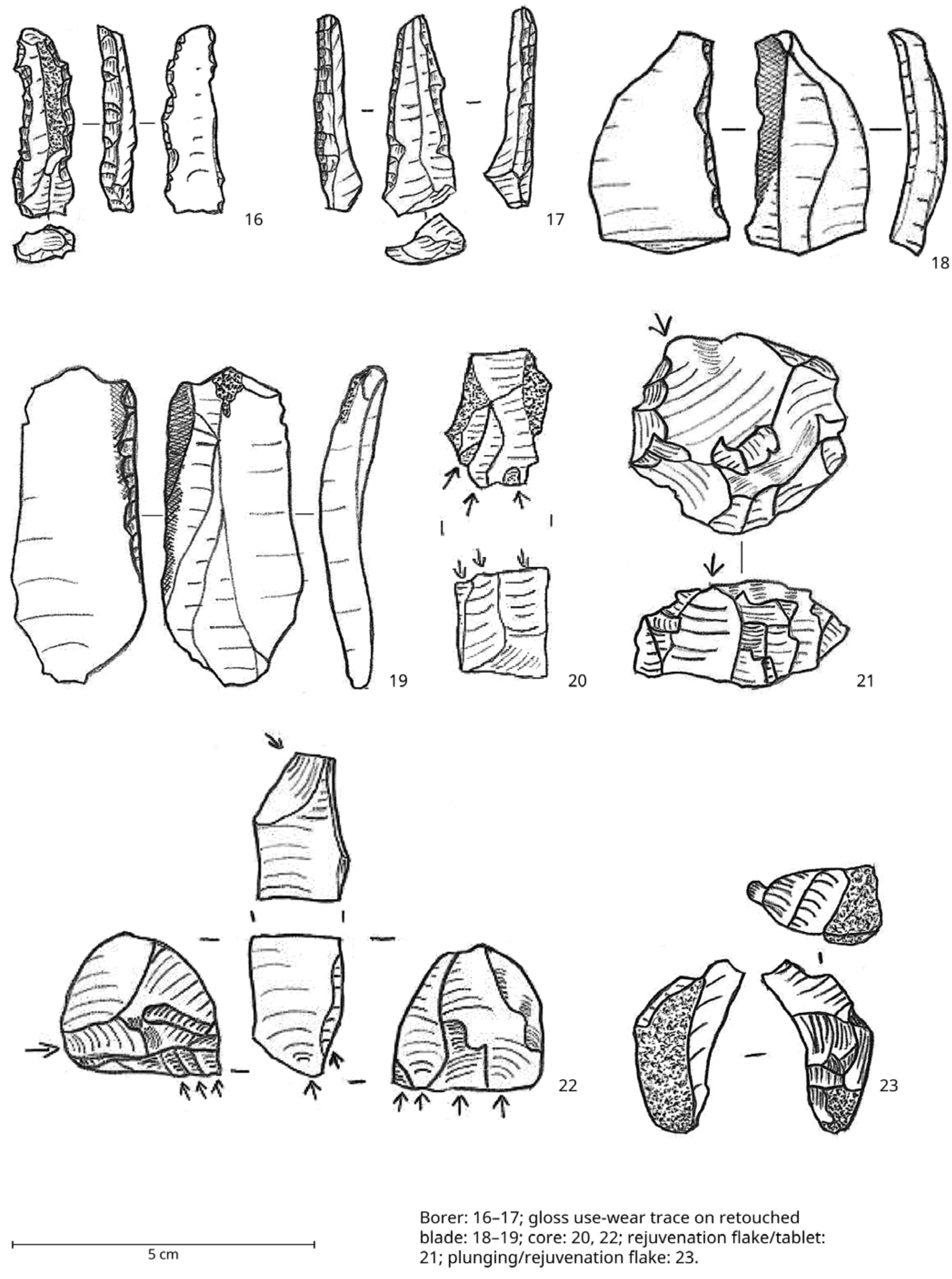

Plate 2. Karancsság (Nógrád county, Hungary). Lithic items from the LBK period (cont.).

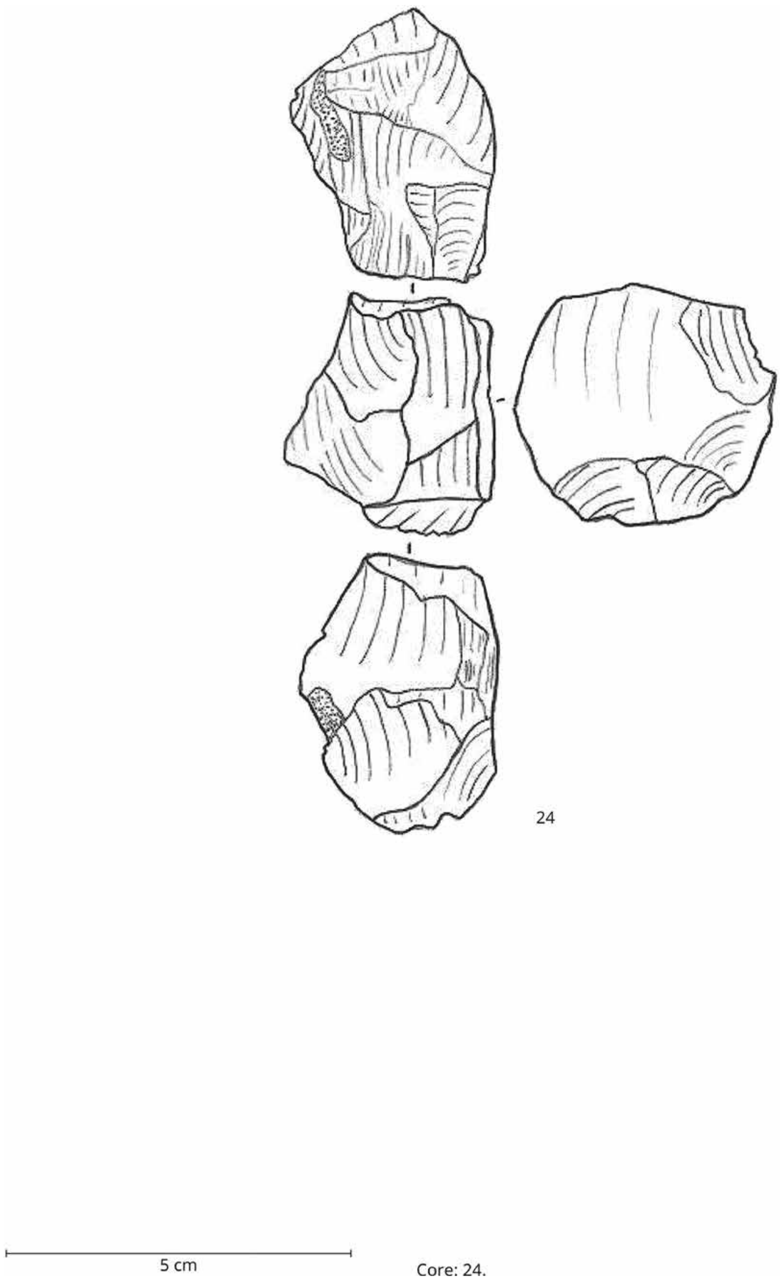

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Plate 3. Karancsság (Nógrád county, Hungary). Lithic items from the LBK period (cont.).

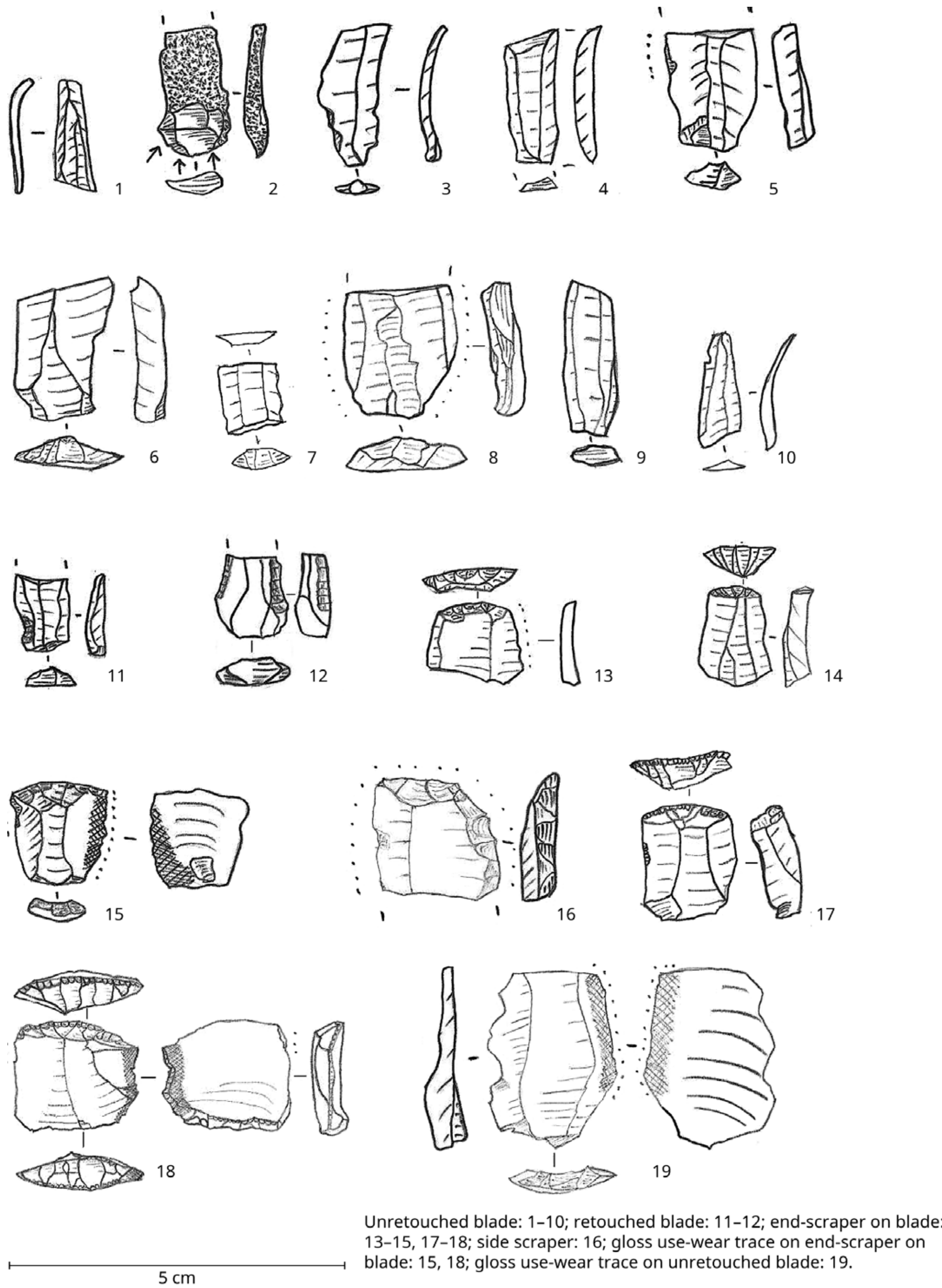

Plate 4. Karancsság (Nógrád county, Hungary). Lithic items from the Lengyel period.

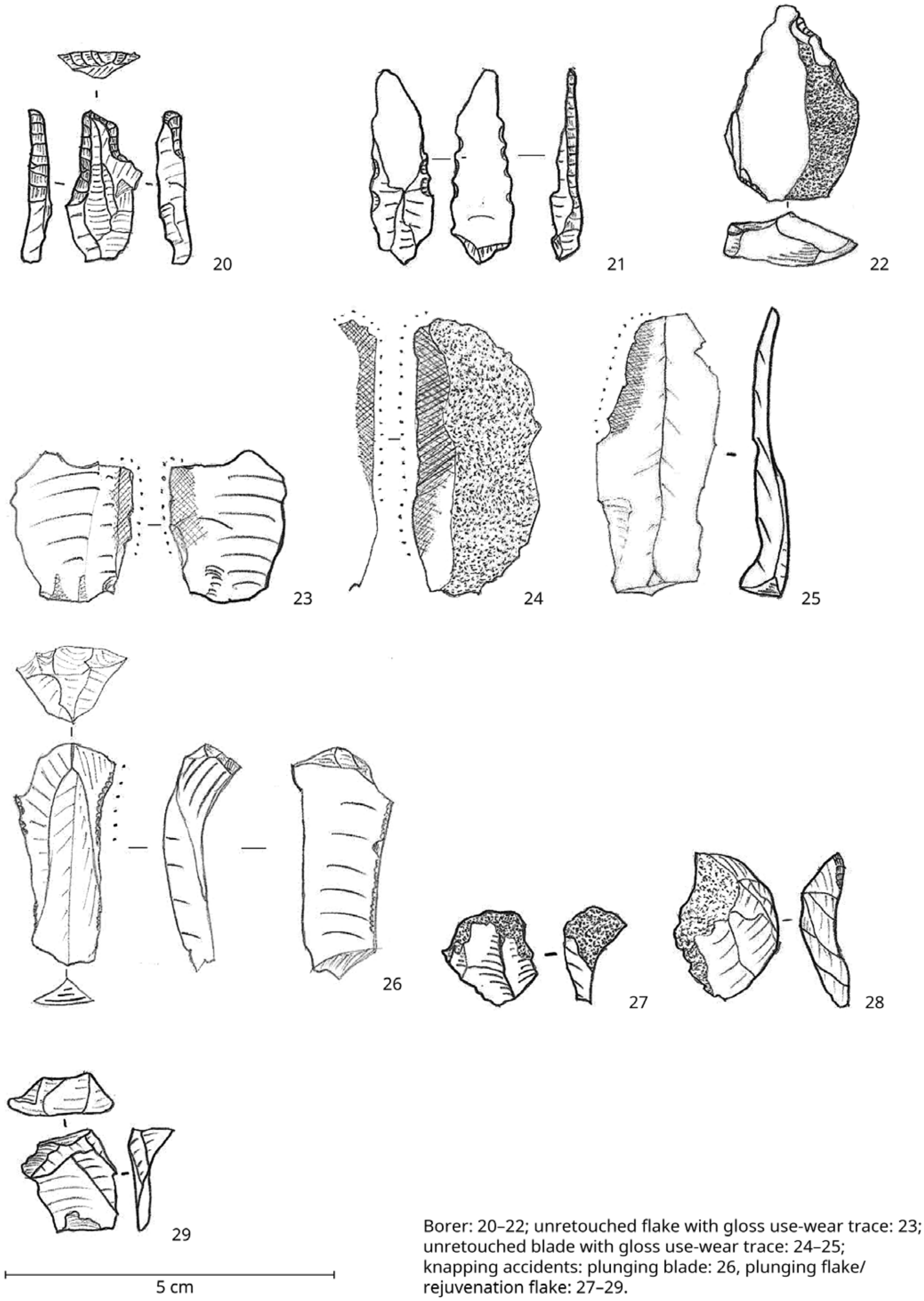

Plate 5. Karancsság (Nógrád county, Hungary). Lithic items from the Lengyel period (cont.).

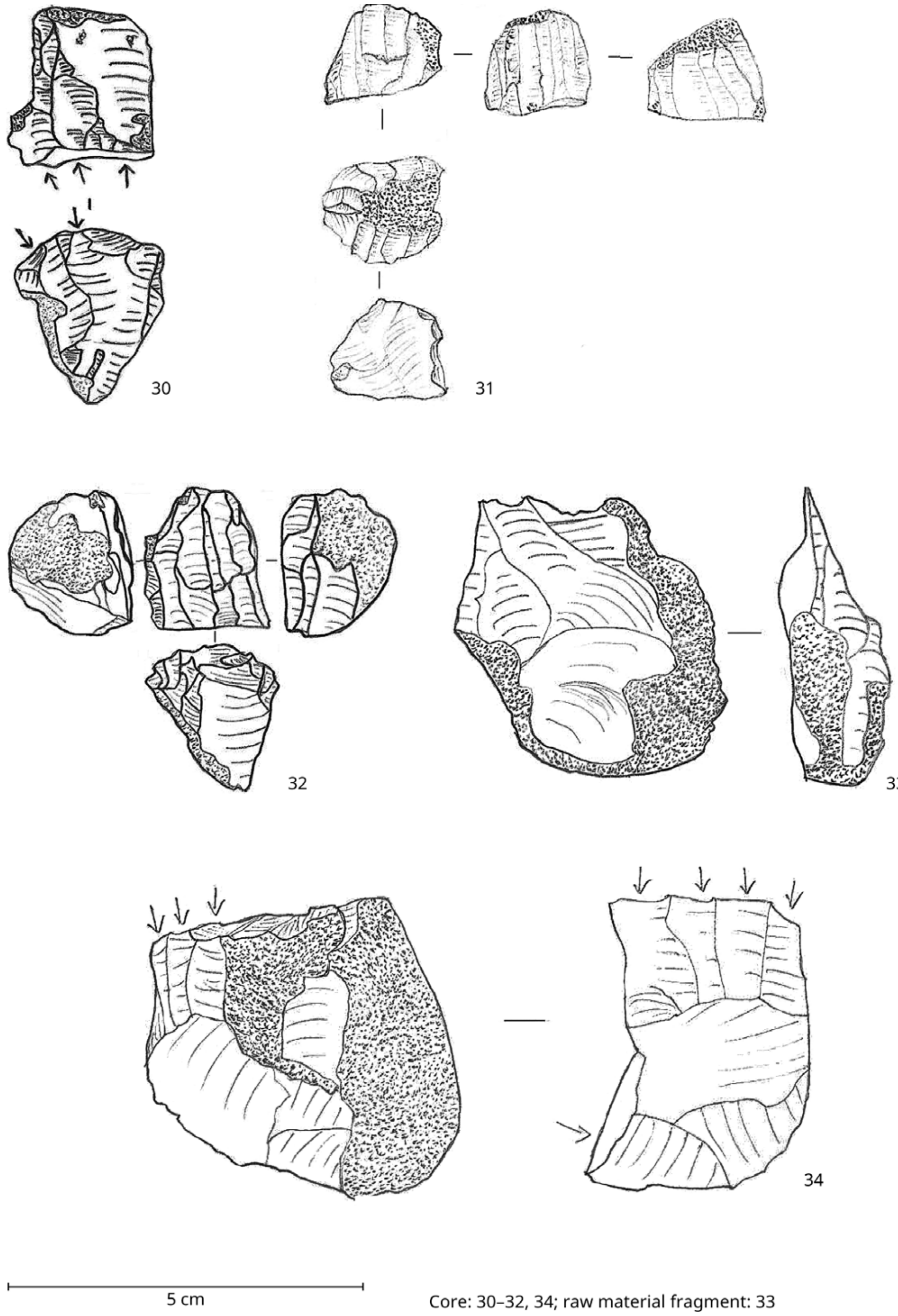

Plate 6. Karancsság (Nógrád county, Hungary). Lithic items from the Lengyel period (cont.).

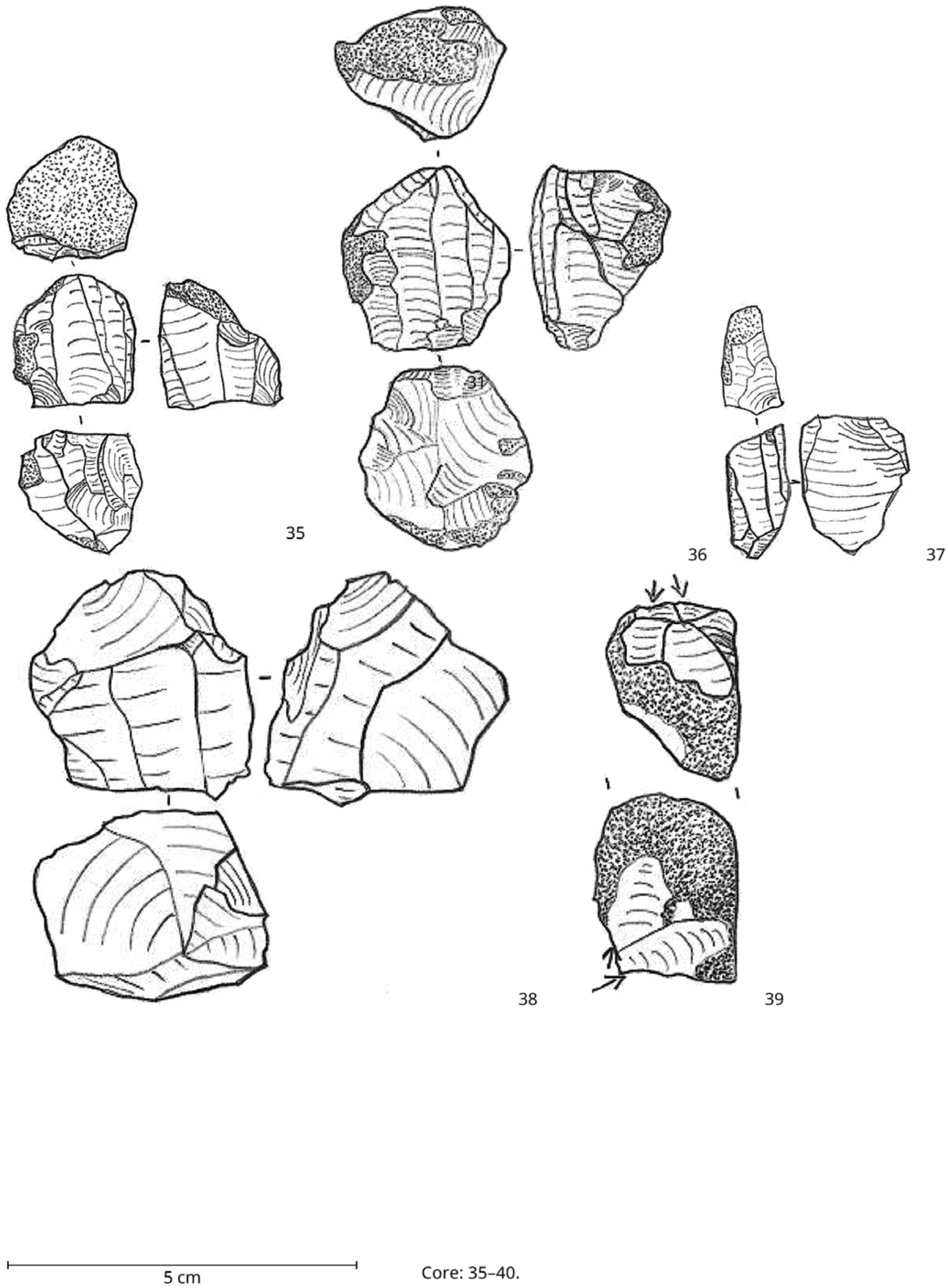

Plate 7. Karancsság (Nógrád county, Hungary). Lithic items from the Lengyel period (cont.).

Appendix

Table with site information.

Site identifier	Municipality	Site toponym	Site type	Period	Culture	Reference
1	Karancsság	Alsó-rétek/Bejövő út	settlement (excavated)	MN, LN	LBK (Music Notes group and Zseliz), Lengyel	in this publication
2	Szécsény	Ültetés	settlement (excavated)	MN	LBK (Music Notes group and Zseliz)	Soós 1982
3	Csesztve	Stalák	settlement (excavated)	LN	Lengyel	T. Dobosi-Tárnoki 1987
4	Bercel	Gutai-lapos	cemetery	LN	Lengyel	Hungarian National Museum, Archaeodatabase
5	Balassagyarmat	OFB-földek	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
6	Csécse	Nagyréti oldal	settlement	MN	LBK	Hungarian National Museum, Archaeodatabase
7	Csécse	Borsósor	settlement	MN	LBK	Hungarian National Museum, Archaeodatabase
8	Csécse	Borsósor II	settlement	MN	LBK	Hungarian National Museum, Archaeodatabase
9	Drégelypalánk	Kis-hegy	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
10	Felsőpetény	Három árok	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
11	Jobbágyi	Vám-part	settlement	MN	LBK (Music Notes group and Zseliz)	Hungarian National Museum, Archaeodatabase
12	Nagyoroszi	Magtár-mögötti-dűlő	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
13	Nagyoroszi	Széles-föld	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
14	Nógrádkövesd	Víztározó és környéke	settlement	LN	Lengyel	Patay 1956; Hungarian National Museum, Archaeodatabase
15	Nógrádmegyer	Tsz major	settlement	MN	LBK (Music Notes group and Zseliz)	Hungarian National Museum, Archaeodatabase
16	Ősagárd	Széles-mező 2	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
17	Pásztó	Hidegvölgy-dűlő 3	settlement	MN	LBK (Zseliz)	Hungarian National Museum, Archaeodatabase
18	Pásztó	Hidegvölgy-dűlő 2	settlement	MN	LBK (Zseliz)	Hungarian National Museum, Archaeodatabase
19	Rétság	Berka-nyugat	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
20	Romhány	Tereskei út	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
21	Romhány	Forrás	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
22	Romhány	Farkasok	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
23	Salgótarján	Egri utca 11	settlement	MN	LBK (Music Notes group and Zseliz)	Hungarian National Museum, Archaeodatabase
24	Szátok	Kis-erdő	settlement	LN	Lengyel	Hungarian National Museum, Archaeodatabase
25	Bánk	Szennyvíztisztító	settlement, cemetery	LN	Lengyel	Hungarian National Museum, Archaeodatabase

Site iden-tifier	Municipality	Site toponym	Site type	Period	Culture	Reference
26	Kálló	Alsó-hegyi földek	settlement, cemetery	LN	Lengyel	Hungarian National Museum, Archaeodatabase
27	Bánk	Templom-megetti-dűlő	surface finds	LN	Lengyel	Hungarian National Museum, Archaeodatabase
28	Bér	Öreg- hegy 2	surface finds	EN	Körös?	Hungarian National Museum, Archaeodatabase
29	Cered	Gyepüs-völgy	surface finds	MN	LBK	Hungarian National Museum, Archaeodatabase
30	Csécse	Bogaras alsó	surface finds	MN	LBK	Hungarian National Museum, Archaeodatabase
31	Csécse	Bogaras alsó II	surface finds	MN	LBK	Hungarian National Museum, Archaeodatabase
32	Csécse	Bogaras felső	surface finds	MN	LBK	Hungarian National Museum, Archaeodatabase
33	Erdőtarcsa	Templomi-tábla	surface finds	LN	Lengyel	Hungarian National Museum, Archaeodatabase
34	Érsekvadkert	Dejtári szőlők alja	surface finds	LN	Lengyel	Hungarian National Museum, Archaeodatabase
35	Érsekvadkert	Murga	surface finds	LN	Lengyel	Hungarian National Museum, Archaeodatabase
36	Érsekvadkert	Malom-úti dűlő	surface finds	LN	Lengyel	Hungarian National Museum, Archaeodatabase
37	Érsekvadkert	Sportpálya utca	surface finds	LN	Lengyel	Hungarian National Museum, Archaeodatabase
38	Hont	Várhegy	surface finds	LN?	Lengyel?	Simán 1993
39	Hont	Csitár	surface finds	LN?	Lengyel?	Simán 1993, 249
40	Hont	Parassapuszta-Kápolna	surface finds	MN, LN	LBK, Lengyel	Hungarian National Museum, Archaeodatabase
41	Kálló	Zsellér-föld	surface finds	EN, MN	Körös?, LBK	Hungarian National Museum, Archaeodatabase
42	Nagylóc	Hárs-völgy	surface finds	MN	LBK	Hungarian National Museum, Archaeodatabase
43	Nagylóc	Hármas határ 2	surface finds	MN	LBK	Hungarian National Museum, Archaeodatabase
44	Nőtincs	Lókos-patak II	surface finds	LN	Lengyel	Hungarian National Museum, Archaeodatabase
45	Pásztó	Feketeribizlis	surface finds	MN	LBK	Hungarian National Museum, Archaeodatabase
46	Patvarc	Öreg Hradistya	surface finds	MN	LBK	Tárnoki 1987; Bánffy 1997
47	Romhány	Diós út	surface finds	LN	Lengyel	Hungarian National Museum, Archaeodatabase
48	Romhány	Fenyves	surface finds	EN	Körös?	Hungarian National Museum, Archaeodatabase
49	Szarvasgede	Kerekdomb	surface finds	MN	LBK	Hungarian National Museum, Archaeodatabase
50	Szügy	Bakó	surface finds	LN?	Lengyel?	Zandler 2009; Hungarian National Museum, Archaeodatabase

EN = Early Neolithic; MN = Middle Neolithic; LN = Late Neolithic; LBK = Linearbandkeramik (English: Linear Pottery culture)

Appendix references

Bánffy, E., 1997. *Cult objects of the Lengyel culture. Connections and interpretation.* Budapest: Archaeolingua Alapítvány.

Dobosi, T.V. and Tárnoki, J., 1987. Excavations on Csesztve-Stalák. *Communicationes Archaeologicae Hungariae*, 40, 5-14.

Patay, P., 1956. Újabb kőkori és kelta leletek Nógrádkövesden és a nógrádi dombvidéken [Late Neolithic and Celtic finds at Nógrádkövesd and in the Nógrád Hills]. *Archaeologiai* Értesítő, 83 (2), 186-191.

Simán, K., 1993. Őskori leletek Nógrád megyében [Prehistoric finds in Nógrád county]. *Nógrád Megyei Múzeumok* Évkönyve, XVIII (1992-1993), 247-254.

Soós, V., 1982. Előzetes jelentés a Szécsény-ültetési zselizi telep feltárásától [Preliminary report from the excavation of the Zseliz settlement at Szécsény-Ültetés site]. *A Nógrád Megyei Múzeumok* Évkönyve, VIII, 7-36.

Tárnoki, J., 1987. Patvarc, Öreg Hradistya ásatásról 1986 [About the excavaton at Patvarc, Öreg Hradistya of 1986]. *Régészeti Füzetek*, 1 (40).

Zandler, K., 2009. ‘Koplyan Alias Bakófalva’ Okleveles és terepbejárási adatok a Csesztvéhez és Szügyhöz tartozó egykori Koplány történetéhez. In: J. Rácz and K. Zandler, eds. *‘Koplyan Alias Bakófalva’ Okleveles* és *régészeti adatok az egykori Koplány történetéhez*. Balassagyarmat: Nógrád Megyei Levéltár, 5-80.

Social and cultural diversity in the later prehistory of the Carpathian Basin: some implications

Eszter Bánffy

The Carpathian Basin is located between the eastern and western Europe and between south-eastern and central Europe, a location that is both central and peripheral. Several aspects of this unique location make it crucial in multiple prehistoric (and historic) epochs. This volume focuses on the archaeological periods beginning with the arrival of the first farmers, who originated in the Balkans, i.e. the Neolithic. Studies of various facets of early food production and sedentary subsistence and of the accompanying structural changes in Neolithic society make up the volume's core, with the emphasis being on the Late Neolithic. The volume also offers some perspective on later further developments and some theoretical contemplations about society in the Early and Middle Bronze Ages. It may seem a little arbitrary to include precisely these regions and periods, without, e.g., any papers on the early to late Chalcolithic that could form a bridge between the earlier (that is, Neolithic) and later (that is, Bronze Age) periods discussed in the volume. However, as is noted in the introduction, the origin of this publication is a session at the 2021 European Association of Archaeologists (EAA) Annual Meeting, held in Kiel. The session's title, 'The Carpathian Basin as a Melting Pot? Perspectives on Social and Cultural Diversity from the Neolithic to the Bronze Age', governs the choice of content of this volume.

As one reads the papers, it becomes clear why it is worth putting together reports on new projects, findings and analyses based on the results gained from multidisciplinary projects. The papers have been grouped into four themes – 'Population and settlement dynamics', 'Social transformations and inequalities', 'Enclosures and communal areas', and 'Economy and subsistence strategies' – to orient the reader, who will observe that the chronological sequence is of secondary importance within the themes. The papers' conclusions often coincide on many aspects, showing that, e.g., settlement dynamics linked with subsistence strategies but also with social transformation. This multi-scalar approach – or, as we might say, this approach that takes into account the interdependence that exists to some extent among the different facets of research into prehistory – is one of the main merits of the volume. The reader will notice that the findings, methods and analyses necessarily overlap, which implies that investigations must take into account each and every piece of available information.

One of the papers in this volume focuses on the beginnings: the arrival of the first farmers. With these first farmers following the major river valley routes northward, some regions, such as the central Balkans, seem to have been intensively settled, while others were not or barely populated, and periods of rapid advance and slower movement alternated until the descendants of the first Balkan farmers reached the southern part of the Carpathian Basin. This latter proved to be an area of deceleration due to several environmental and social factors that eventually brought the northward advance to a standstill. Early farmers and local forager groups were probably prompted to change their lifeways creatively, probably also taking over coping mechanisms from each other. Eventually, this proved successful for both groups, albeit that the results were different. The population dynamics of these processes are studied in the orbit of the first farmers who arrived in the Carpathian Basin, at the onset of the 6th millennium cal BC, who form part of the Starčevo formation, found in the western part (Transdanubia), and the Körös – Criş formation, found in the Serbian and Romanian Banat, eastern Hungary (the Alföld) and western Romania. The authors used the summed calibrated probability distribution (SCPD) method to interpret the radiocarbon dates. While the SCPD method, which is increasingly used, comes with certain risks in extrapolation, some booms and busts within the demography of the Early Neolithic seem to be a convincing inference. Exploring the links between traditional archaeological results and results gained from molecular bioarchaeology leads to two inherently necessary follow-up research questions: What were the twofold identities (biological and cultural) in a given community? What were the population patterns? A similarly necessary step in the analyses is combining demographic change, both increases and decreases, with the ability to adapt with subsistence strategies, and with the degree of success in building networks with close and distant neighbours. The study of Early Neolithic palaeo-demography and its case studies are, in this way, perfectly apt for viewing the entire volume through the lens of adaptation reflected in population increase or decline over many centuries. As it was chosen as the first paper, it goes beyond chronological considerations and provides an excellent launching point for the papers that follow.

To highlight some important aspects of the book, I note that it is striking to see how new projects, connected to well-known sites with old excavations, allow interpretations that raise doubts about or even profoundly change some earlier views thought to be carved in stone. New fieldwork and (re-)analysis of the results of old and new excavations and surveys have brought ground-breaking results, and in observing this, it is striking how much the multidisciplinary nature of the new approaches appears to be of pivotal importance. This is the case for the new studies at Vráble and especially for the long-known-about and renowned site of Szegvár. The earlier research history at Szegvár, as becomes clear from the details provided in the paper, was full of misunderstandings and misinterpretations. The application of novel methods originating in the natural sciences, including spatial analyses and complex statistical approaches, is unavoidable today. However, it should be self-evident that these methods, as well as the bioarchaeological results, must be linked and compared with traditional archaeological data. The integration of the resulting dataset, including both old information and data from new investigations, may enable all results to be channelled into the larger archaeological and even social narrative.

Another important aspect is the varying scales, of sites, microregions and larger areas. The essential message from reading this volume is that nothing stands alone: individual sites in different parts of the Carpathian Basin, such as Gradište, Borđoš, Szegvár, Jelšovce, or Kiarov, must be viewed as being embedded in a landscape and, perhaps even more importantly, in a cultural and communications network. A beautiful example of the vital role of networks in archaeological analysis is the site of Karancsság, where the raw material sources used speak of a long-standing tradition

based on practical aspects of lithic tool making and cultural communication that are both coeval and diachronous. The paper shows how knowledge transfer shapes cultural formations (and perhaps vice versa). Admitting that no site can stand alone in the landscape, its authors place micro-regional research at the forefront of their investigations. Elsewhere in the volume, research in the Žitava Valley, on the north-western edge of the Carpathian Basin, brilliantly shows how sites and settlement patterns evolved from the LBK, to the Lengyel culture, and to the Bronze Age, thousands of years later. This is a perfect case for demonstrating that both change and repetition or persistence can be ascribed to environmental adaptation and cultural tradition.

The book underscores the transformative impact of new projects on well-known sites, revealing how (re-)interpretations of both old and newer excavations challenge previously held views. One cannot underestimate the revolutionary step-change that occurred in our understanding of prehistoric settlements following the expanded use of non- (or minimally) destructive methods – including geomagnetic analyses and susceptibility measurements of coring, as well as aerial archaeology through the use of drones and light detection and radar (LiDAR) scanning. Over the past two decades, newly obtained 'maps' of sites and newly detected socio-cultural parameters have changed our understanding of the settlement size, intensity, patterns and variety on the scales of the site and the region. The multi-scalar computational modelling of the Tisza floodplain catchment provides an appropriate framework for combining environmental and socio-cultural variables with site locations, i.e. settlement preferences, in the Neolithic phases. It may seem self-explanatory that apart from soil preferences, water access is one of the primary stimulating effects for any subsistence activity in a riverine landscape, let alone agricultural-type subsistence. Yet, hydrological mapping also shows the problematic aspects of settling in such an environment: fluctuations in the location of sites reflect the continual adjustment that must have taken place in response to regular flooding and higher water levels, whether seasonally or within even shorter periods. This analysis also sheds light on the effects of a long-standing bias in the history of archaeological research, when excavations were generally concentrated only at the tell mounds themselves. We now learn that tell sites emerged under wetland circumstances in the Neolithic, and that such circumstances were the norm before the implementation of river and water level regulation in the Alföld lowland. The paper can serve as an introductory analysis of the effects of various biases and mistakes in the history of research relating to attempts to estimate settlement size and the spatial extent of connected sites and to reconstruct communication networks. It will be an utterly exciting and vital study to compare the circumstances described in the paper with fluctuations in mobility and diet described based on stable isotope analyses.

A wide range of examples in several papers show the power and the possibilities of combining novel methods and analyses with traditional ones. One of these case studies focuses on the Borđoš terrace – on the site of Borđoš itself and on coeval sites nearby. The palaeoclimatic, archaeobotanical and geomorphological analyses combined shed light on some features detected in the settlements as being related to coping with harsh circumstances, such as a dominant, strong wind. As a direct outflow from this analytical result on the landscape around Borđoš, a series of Late Neolithic sites were investigated with non-destructive methods. As has been the case everywhere around well-known tell sites, the discovery of the ubiquity of earlier – previously undetected – ditch systems is one of the most decisive findings to change our understanding of life in a Neolithic tell settlement. As has been recently and widely published here and in other publications, settlement plans, the orientation of houses, and strong local preferences are further striking new results that have been achieved thanks to geophysical survey.

The east Hungarian Late Neolithic tell settlements have gained an almost entirely new reading. The new knowledge on the emblematic tell settlement at Szegvár is significant not only because of the profoundly new information, correcting our earlier knowledge, but also because it changes the understanding of the Late Neolithic tell orbit in the middle section of the Tisza riverine area, yielding a picture of not only close similarities but also a significant number of differences, local characteristics, reflecting the tastes, choices and very local traditions of the inhabitants. The Szegvár tell mound had a settlement structure oriented towards a focal area, and this focal concentration can also be observed on a larger scale, in the multiple ditches ringing the settlement and in the orientation of the entire system of satellite sites around the tell mound. The long and complicated research history of Szegvár has been expanded with this fascinating new facet. The paper on recent research at Gradište, on the south-eastern edge of the Alföld, forms an excellent complement on the significance of more minor, lesser-known tell sites in the lowland landscape.

The book contains a series of detailed research papers on various microregions that focus on the broader social context, such as the Žitava Valley in the north-west, and the area of the Szegvár tell site in the middle section of the Tisza Valley, which is also a micro-region with an abundance of tell mounds and their satellite settlements. Similarly, exploring the Neolithic environment and its social context within the micro-region of the Serbian Banat is an essential part of the volume. The scrutiny of individual micro-regions, however, does not appear as a series of isolated investigations in the book: the reader increasingly becomes part of the process whereby the analysis of sites or small regions becomes embedded in the analysis of larger scales. The book balances the preliminary reports and broader analyses, as in the multidisciplinary analysis of the Serbian site of Gradište, which shows a compound subsistence strategy based mainly on cattle herding in a location that sits at the interface between the two larger Late Neolithic entities in this region: the Tisza world and the Vinča world.

Scales vary in geographical terms and open up the ‘big picture’ of multifaceted interpretations. Moreover, this variable ‘zooming in and out’ happens in temporal terms, too, in the paper that follows immediately after the paper on Late Neolithic liminal zone analysis. This paper broadens the scales and the question of social power by comparing two cases that could not be more distant from each other. Tamás Polányi’s approach to studying agent-based historical transformations through mortuary analyses involves comparing examples of recent deaths caused by gun violence in the United States with those in a Middle Bronze Age micro-region in the western part of the Carpathian Basin. Yet, by highlighting the multifaceted meanings of single proxies and the synchronisation of their roots in expressing motivations, it is possible to compare these phenomena. Polányi concludes that death, in whatever form or time it appears, becomes a triggering effect to restructure or rearticulate social relations. It is an intriguing experiment using two very different phenomena. However, the ‘contradictory consciousness’, as the accompanying circumstance is called, reflects similar or at least comparable details and thus opens up avenues for seeking similar structures in distant phenomena.

The framework of the volume is, somewhat unusually, a geographical region and not a particular temporal section of prehistory. Yet, the editors (and, previously, the EAA session organisers) grouped papers focusing on similar research questions, using various analytical methods, in the Neolithic and the Bronze Age. Understanding an area’s history of research is pivotal in understanding the new challenges accompanying the ‘third science revolution’. In our efforts to apply novel methods and interpret all proxies correctly and in combination, a key question remains: What were the internal and external factors of social transformations during the initial phases and the following Neolithic and Bronze Age societies in an area (in this

case the Carpathian Basin) that significantly influenced the prehistory of the wider area (in this case both the south-eastern part of eastern Europe and central Europe)?

The research and the interpretative efforts detailed in this volume are a tremendous success, but they challenge archaeologists to find ways for future research to focus on the right questions. Questions that may pave the way to seeing marginal, frontier zones and liminal boundaries suddenly become core areas of newly emerging cultural and social formations; to observing a constant fluidity between separation and connection; and to learning from prehistoric examples when investigating later historical processes or, ultimately, current tendencies. The most outstanding merit of the present volume may be that it helps us understand the timing and tempo, the rhythm and drive, of settlement organisation from the site scale to the supra-regional scale – and that it proffers archaeology as a valuable tool to understand variation in universal human behaviours.

List of authors (in order of appearance)

Kata Furholt
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
kata.furholt@ufg.uni-kiel.de

Margaux L.C. Depaermentier
Department of Archaeology, Faculty of History
Vilnius University
Universiteto g. 7, 01513 Vilnius, Lithuania
margaux.depaermentier@if.vu.lt

Michael Kempf
Quaternary Geology, Department of Environmental Sciences
University of Basel
Bernoullistrasse 32, 4056 Basel, Switzerland
michael.kempf@unibas.ch
Department of Archaeology, Faculty of History
Vilnius University
Universiteto g. 7, 01513 Vilnius, Lithuania

Martin Furholt
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
martin.furholt@ufg.uni-kiel.de

Tamara Blagojević
BioSense Institute
University of Novi Sad
Dr Zorana Đinđića 1, 21000 Novi Sad, Serbia
tamara.blagojevic@biosense.rs

Marko Porčić
Department of Archaeology, Faculty of Philosophy
University of Belgrade
Čika Ljubina 18-20, 11000 Belgrade, Serbia
mporcic@f.bg.ac.rs

Sofija Stefanović
Department of Archaeology, Faculty of Philosophy
University of Belgrade
Čika Ljubina 18-20, 11000 Belgrade, Serbia
smstefan@f.bg.ac.rs

Gerrit Günther
Department of Geography
Kiel University
Ludewig-Meyn-Straße 8, Kiel, Germany
guenther@geographie.uni-kiel.de

Aleksandar Medović
Museum of Vojvodina
Dunavska 35-37, 21101 Novi Sad, Serbia
aleksandar.medovic@muzejvojvodine.org.rs

Robert Hofmann
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
robert.hofmann@ufg.uni-kiel.de

Tijana Stanković Pešterac
Museum of Vojvodina
Dunavska 35-37, 21101 Novi Sad, Serbia
tijana.pesterac@muzejvojvodine.org.rs

Ildiko Medović
Museum of Vojvodina
Dunavska 35-37, 21101 Novi Sad, Serbia
ildiko.medovic@muzejvojvodine.org.rs

Stefan Dreibrodt
Institute for Ecosystem Research
Kiel University
Olshausenstrasse 100, D-24106 Kiel, Germany
sdreibrodt@ecology.uni-kiel.de

Liudmyla Shatilo
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
Institute of Archaeology
National Academy of Sciences of Ukraine
Heroyiv Stalinhrada Ave. 12, 04210 Kyiv, Ukraine
milashatilo@gmail.com

Fynn Wilkes
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
fwilkes@roots.uni-kiel.de

Darko Radmanović
Museum of Vojvodina
Dunavska 35-37, 21101 Novi Sad, Serbia
darko.radmanovic@muzejvojvodine.org.rs

Nikola Mrkšić
Museum of Vojvodina
Dunavska 35-37, 21101 Novi Sad, Serbia
nikola.mrksic@muzejvojvodine.org.rs

Till Kühl
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
tkuehl@roots.uni-kiel.de

Sebastian Schultrich
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
sschultrich@sfb1266.uni-kiel.de

Raško Ramadanski
Museum of Bečej
Glavna 25, 21220 Bečej, Serbia
r.ramadanski@gmail.com

Lenkskaya Martinova
Independent researcher
lenkskaya.martinova@yahoo.com

Pál Raczky
Institute of Archaeological Sciences
Eötvös Loránd University
Múzeum krt. 4/B, H-1088 Budapest, Hungary
raczky.pal@gmail.com

András Füzesi
Hungarian National Museum
Múzeum krt. 14-16, H-1088 Budapest, Hungary
fuzesia@gmail.com

Gábor Mesterházy
Hungarian National Museum
Múzeum krt. 14-16, H-1088 Budapest, Hungary
gabor.mesterhazy@gmail.com

Eszter Bánffy
HUN-REN RCH Institute of Archaeology
Centre of Excellence of the Hungarian Academy of Sciences
4 Tóth Kálmán utca, H-1097 Budapest, Hungary
eszter.banffy@abtk.hu

Knut Rassmann
Römisch-Germanische Kommission des Deutschen Archäologischen Instituts
Palmengartenstr. 10-12, D-60325 Frankfurt am Main, Germany
knut.rassmann@dainst.de

Máté Stibrányi
Hungarian National Museum
Múzeum krt. 14-16, H-1088 Budapest, Hungary
stibranyi@gmail.com

Gábor Serlegi
Hungarian National Museum
Múzeum krt. 14-16, H-1088 Budapest, Hungary
serlegig@gmail.com

Miroslav Marić
Balkanološki Institut SANU
Knez Mihailova str. 35/IV, Belgrade, Serbia
miroslav.maric@bi.sanu.ac.rs

Silvia Amicone
Competence Center Archaeometry-Baden-Württemberg
University of Tübingen
silvia.amicone@uni-tuebingen.de
Institute of Archaeology
University College London

Jelena Bulatović
Laboratorija za Bioarheologiju Filozofski Fakultet
Univerzitet u Beogradu
Čika Ljubina 18-20, Belgrade, Serbia
jelena.bulatovic@f.bg.ac.rs

Nemanja Marković
Arheološki Institut
Knez Mihailova str. 35/IV, Belgrade, Serbia
nemamarkovic@gmail.com

Neda Mirković Marić
Međuopštinski zavod za zaštitu spomenika kulture
Trg Slobode 1-3, Subotica, Serbia
nmirkovicus@gmail.com

Tamás Polányi
Department of Anthropology
Northwestern University
tpolanyi@northwestern.edu

Henry Skorna
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
h.skorna@ufg.uni-kiel.de

Ivan Cheben
Institute of Archaeology
Slovak Academy of Sciences
Akademická 2, 949 21 Nitra, Slovakia
ivan.cheben@savba.sk

Alena Bistáková
Institute of Archaeology
Slovak Academy of Sciences
Akademická 2, 949 21 Nitra, Slovakia
alena.bistakova@savba.sk

Zuzana Hukeľová
Institute of Archaeology
Slovak Academy of Sciences
Akademická 2, 949 21 Nitra, Slovakia
zuzana.hukelova@savba.sk

Maria Wunderlich
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
m.wunderlich@ufg.uni-kiel.de

Till Kühl
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
t.kuehl@ufg.uni-kiel.de

Nils Müller-Scheeßel
Institute of Pre- and Protohistoric Archaeology
Kiel University
Johanna-Mestorf-Str. 2-6, D-24118 Kiel, Germany
nils.mueller-scheessel@ufg.uni-kiel.de

Slobodan B. Marković
Department of Geography, Tourism and Hotel Management, Faculty of Science
University of Novi Sad
Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia
slobodan.markovic@dgt.uns.ac.rs

György Sipos
Department of Physical Geography and Geoinformatics
Szeged University
Egyetem Street 2-6, H-6720, Szeged, Hungary
gysipos@geo.u-szeged.hu

Sarah Pleuger-Dreibrodt
School of History, Classics and Archaeology
University of Edinburgh
Teviot Place, Edinburgh EH8 9AG, United Kingdom
sarahpleuger@archaeozoo.org

Randall J. Schaetzl
Department of Geography, Environment, and Spatial Sciences
Michigan State University
128 Geography Building, East Lansing MI 48824, United States
soils@msu.edu

Milivoj B. Gavrilov
Department of Geography, Tourism and Hotel Management, Faculty of Science
University of Novi Sad
Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia
gavrilov.milivoj@gmail.com

Milica G. Radaković
Department of Geography, Tourism and Hotel Management, Faculty of Science
University of Novi Sad
Trg Dositeja Obradovića 3, 21000 Novi Sad, Serbia
milica.radakovic.95@gmail.com

Desanka Kostić
Department of Biology and Ecology Faculty of Science
University of Novi Sad, 21000 Novi Sad, Serbia
desanka.kostic@dbe.uns.ac.rs

Noémi Beljak Pažinová
Department of Archaeology, Faculty of Arts
Constantine the Philosopher University in Nitra
Tr. A. Hlinku 1, 949 01 Nitra, Slovakia
nbpazinova@ukf.sk

Katarína Šimunková
Department of Archaeology, Faculty of Arts
Constantine the Philosopher University
Tr. A. Hlinku 1, 949 01 Nitra, Slovakia
ksimunkova@ukf.sk

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